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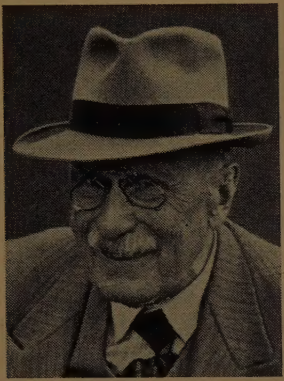

BERGMESTER ANDREAS HOLMSEN

Minnetale holdt 16. februar 1956.

AV CARL BUGGE.

Bergmester ANDREAS HOLMSEN døde 15. desember 1955. Det var et langt og rikt bergmannsliv som herved fikk sin avslutning.

Andreas Holmsen var en meget særpreget personlighet. Hans interesser og kunnskaper strakte seg over vide felter, innen både vitenskap og praksis. Han likte særlig godt den vitenskap som kunne ha betydning for det praktiske liv. Foruten bergfagene interesserte han seg spesielt for hydrologi og fysisk geografi.

Andreas Holmsen var født på Røros 23. mai 1869, sønn av hyttemester Andreas Holmsen og Hilda Stengel. Han ble student 1888, tok bergeksamen ved universitetet 1893 og ble samme åt ansatt ved Røros kobberverk men forlot Verket allerede i 1895, da han ble ansatt som hydrograf ved Statens Vassdragsvesen. I 1916 ble han sekretær i Handelsdepartementet, bergkonsulent i 1918 og underdirektør i samme departement i 1921. Han var her til han i 1932 ble utnevnt til bergmester i Østlandske bergdistrikt. I 1934 ble han også bestyrer av Vestlandske bergdistrikt, og siden 1937 var han pensjonert.

I sine yngre år studerte Holmsen i Zürich, München, Wien og Paris. Våren 1920 ble han sendt av regjeringen til Paris og London i anledning av spørsmål som sto i forbindelse med Norges overtagelse av Svalbard. Han har vært oppnevnt som medlem av flere offentlige kommisjoner og komiteer, således komiteen av 1919 til utarbeidelse av bergverksordning for Svalbard. Ellers har hans hovedinteresse vært knyttet til fysisk geografi i hvilket fag han foreleste ved Universitetet 1905—09 og han var også en årrekke oppnevnt som sensor i faget.

For geologene er det av særlig interesse at han var en av stifterne av Norsk Geologisk Forening. Holmsens hjem var i høy grad preget av vitenskap, enn mere fordi han var gift med den kjente botaniker, amanuensis dr. THEKLA RESVOLL (22. mai 1871—14. juni 1948).

I sitt arbeide fikk Holmsen utmerket kjennskap til vårt vidstrakte land. Som hydrograf undersøkte han alle større innsjøer og elver i landet. Som bergkonsulent og underdirektør i Handelsdepartementet ordnet han med administrative saker angående geologi og bergvesen. Det var i 1921 Norges Geologiske Undersøkelse ble overflyttet fra Kirkedepartementet til Handelsdepartementet etter innstilling av en komité bestående av Brøgger, Goldschmidt, C. F. Kolderup, Holm Holmsen, Reusch og Alfred Getz. Ved senere ny ordning av departementene kom N. G. U. under Industridepartementet. Det var meget heldig at man i departementet hadde en så kyndig mann som Holmsen til å ordne med sakene. Han var kunnskapsrik og samtidig meget behagelig å samarbeide med.

Holmsen har forfattet mange publikasjoner, både store arbeider og en mengde artikler i tidsskrifter og dagspressen.

1. I 1898 utkom «Seiches i norske indsjøer.» Arch. f. Math. og Nat. vid.
2. Limnologiens utvikling i de senere år. Forh. ved Skand. Naturforskermøte i Stockholm 1898.
3. Isforholdene ved de norske indsjøer. 12 Pl. 271 sider. Videnskabsselskabets skr. 1901.

   For disse studier fikk Holmsen Kronprinsens gullmedalje. Av Vassdragsvesenets beskrivelser over norske vassdrag i den tid Holmsen var hydrograf der er Glommens (1903) og Skiensvassdragets (1907) beskrivelse vesentlig og Numedalslågens helt av ham.
4. Vore større indsjøer. Geografisk selskabs aarbok nr. 10.
5. Avløpet i endel norske elver og den iakttagne nedbør. Avhandlingen er trykt i Festskrift til professor Amund Helland på hans 70 årsdag 11. okt. 1916. H. Aschehoug & Co.

6. En isdemmet sjø i Norge i Nutiden. Norsk geogr. tidsskr. B. VI. 1937.
7. The Mining Industry in Norway. Norsk Geogr. tidsskrift B. VII h. 5—8—1939.
8. Røros Verk og Røros Bergstad for 50 år siden. Tidsskr. f. Kjemi, Bergvesen og Metallurgi nr. 8, 1944.

Holmsen har gitt bidrag til Salomonsens Konversationsleksikon, Aschehougs Illustrert norsk Konversationsleksikon og General Per Nissens Økonomisk geografisk Atlas over Norge.

I mange år var Holmsen Professor Hellands medarbeider for å samle opplysninger til det store verk «Norges Land og Folk».

Han fortsatte sine studier også i senere år og hadde bl. a. under arbeide et manuskript om sammenligning mellom solflekkperiodene og vannføringen i norske elver.

Gjennom sitt arbeide fikk Holmsen en stor kreds av bekjente. Det var alltid interessant å tale med denne særpregete personlighet. Det er mange som vil minnes ham. Vi hedrer hans minne.

PUTESTRUKTURER, SANDSTENSGANGER, KULLBLENDE ETC. I ROMBEPORFYR-LAVA VED SØNSTERUD, TYRIFJORDEN

Pillow structure, Sandstone dykes, Coal blend etc. in Permian Rhomb porphyry Lava at Sönsterud, Tyrifjord, Oslo Region.

BY
JOHANNES A. DONS

Riksveien Oslo—Hønefoss passerer Krokskogens lavafelt i en mengde gode skjæringer. Ved Sønsterud ses nydelige snitt i den laveste av rombeporfyrene, RP_1; og her er også grensen mot den underliggende basalt B_1 blottet. Lokaliteten som ligger ved den sydøstlige gren av Tyrifjorden har tidligere spilt en viktig rolle i geologisk utforskning av Oslofeltet. Kjerulf har således i flere avhandlinger gjengitt profiler herfra, hvor han påviser det som nå kan kalles den subpermiske diskordans (bl.a. KJERULF 1865).

Senere fremholdt Brøgger gjentagne ganger i sine publikasjoner (bl.a. BRØGGER 1890) at Kjerulf ga en feil tydning av forholdene. Med bl.a. Sønsterud som et av eksemplene hevdet han generelt at det langs alle lavaåsene var forkastninger, og at disse forårsaket det observerte forhold — nemlig at lavadekkene ikke alltid lå i kontakt med den downtonske sandsten.

Etter nye undersøkelser blant annet ved Sønsterud i 1912 og 1921 (BRØGGER 1931) erklærte Brøgger seg uforbeholdent enig med Kjerulf. Da hadde allerede K. Rode, en elev av H. Cloos i 1930 publisert resultater av sine undersøkelser i 1925 av profilet langs Tyrifjorden, hvor han slutter seg helt til Kjerulfs oppfatning på dette punkt. Rode beskriver også i detalj lagfølgen og forkastningene ved Sønsterud, (RODE 1930).

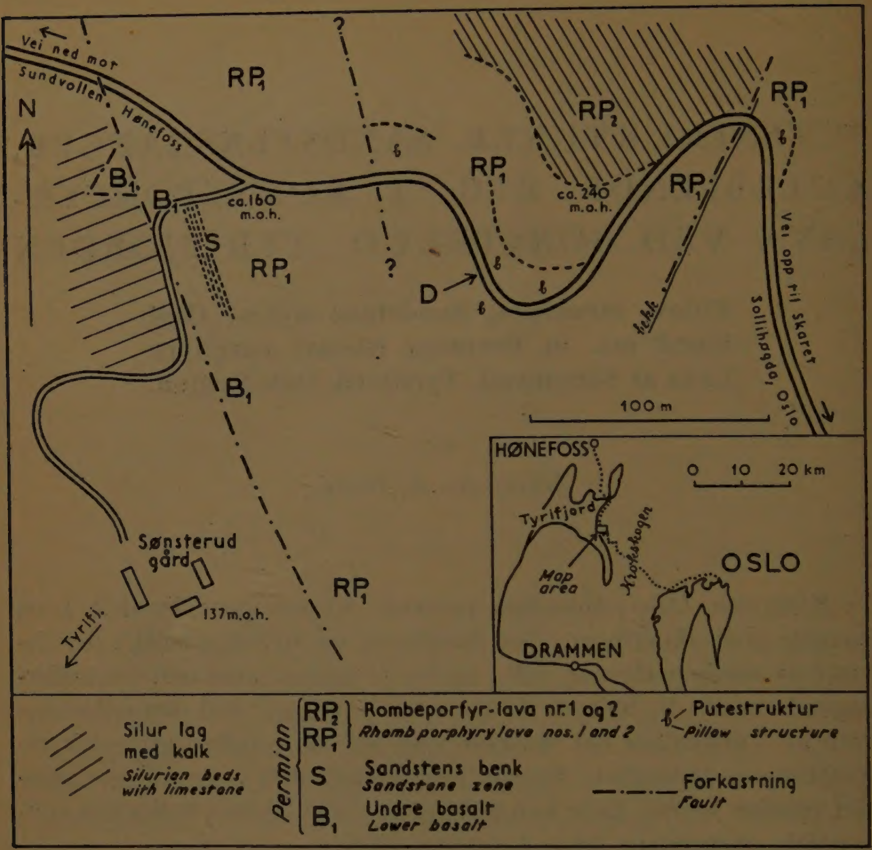

Fig. 1.

På student-ekskursjoner har vi ofte stanset ved Sønsterud for å se bunnen av lavaserien og den sub-permiske diskordans, uten egentlig å få ordentlig klarhet i forholdene. Undersøkelser foretatt i 1953 og 1954 har vist at lokaliteten enda kan gi nye bidrag til forståelse av de skiftende forhold i permtiden. 1) I silurkalk finnes det et tilsynelatende isolert felt av basalt. 2) Det er en sandstensbenk over basaltlavaen. 3) Det er kullblende i basalt, sandsten og den overliggende rombeporfyrlava. 4) Rombeporfyrlavaen har en markert putestruktur og tallrike sandstensganger. Undersøkelsene er utført med bidrag fra Nansenfondet.

1) *Isolert felt av basalt i silur-kalk.*

Foldet silur-kalk grenser inn til basalt B_1. Dette sees i gårdsveien som fra hovedveien Oslo—Hønefoss fører ned til Sønsterud gård, se fig. 1. Perm-sedimentene, inklusive kvartskonglomeratet som skulle finnes under basalten mangler nær hovedveien på grunn av en NNW—SSE gående forkastning. Det er grunn til å tro at det blant annet er denne forkastning som har fått Brøgger til å hevde teorien om forkastninger langs lava-åsene. Kalken, tilhørende etg. 7—9 er foldet og danner her en synklinal med foldningsakse NE. På vestsiden av gårdsveien ses tydelig virkningen av kjemisk oppløsning på kalkstensoverflater. Det er fremkommet et karstlandskap i miniatyr.

I kalken, nær forkastningen ble det under en ekskursjon funnet et felt, ca. 15 m^2, av en finkornet basisk bergart. Grenseforholdene mot forkastningen var ikke synlig på grunn av overdekning. Vår første tanke var at det her forelå et snitt gjennom en tilførsels-kanal for basaltlavaen. Det viser seg nå ved senere undersøkelser at feltet i horisontalsnitt er trekantet og begrenset av breksiert kalk med blant annet spor av nydannet plagioklas. Bergarten, en basalt av samme type som basaltlavaen B_1 like ved, antas å grense inn til hovedforkastningen, og dens beliggenhet forklares som fremkommet ved uregelmessigheter i forkastningssonen.

2) *Sandstensbenk over basaltlavaen.*

I Kolsås-profilet følger rombeporfyrlavaen RP_1 direkte over basaltlavaen B_1. I området øst og nordøst for Oslo er det et kvartsrikt sediment mellom de to lavaer. Tilsvarende sediment er nå funnet her i vest. Observasjonene skriver seg fra Sønsterud ved stedet merket S på kartskissen fig. 1. I den dype kløften hvor bekken Asdøla fra Krokskogen kommer ned, til Lierdalen 3 km S for Sylling fant jeg tilsvarende forhold, altså en sandstensbenk av varierende mektighet.

Basalten ved Sønsterud er etter makroskopisk bestemmelse, av den ikke porfyriske type. Slip viser pyroxen, oligoklas og pseudomorfoser etter olivin i en finkornet grunnmasse. Lavaoverflaten er skrukket og blæret. Blærerommene er fylt med kalkspat og til dels kvarts. Tett hematitt (påvist ved røntgen etter forutgående magnetisk separasjon) farger overflaten rød og fyller mindre hull og sprekker i den aller øverste del av lavabenken. Hematitt er også bindemidlet i de underste par millimetre av sandstens-benken over. Denne anrikning av hematitt kunne tydes som en utfelling på overflaten under lavaens størkning. Antakelig skyldes det imidlertid en intens oksydasjon av lavaens jernholdige mineraler i tiden før sanden ble avsatt. Liknende jernoksydrike lavaoverflater med sandsten er observert i Nittedal, f.eks. mellom RP_1 og RP_2 og mellom RP_7 og RP_8 (SÆTHER 1946).

Sandstenen ligger som en gråsvart $^1/_2$—1 m mektig benk. Kvartskorn, 0.1—0.5 mm i diameter, utgjør den vesentlige del av bergarten, Fig. 7. En del korn består av flere kvarts-individer. Undulerende utslukning er alminnelig. Feltspatkornene (perthit, oligoklas-andesin og mikroklin?) er av samme størrelse som kvartskornene. Noe granat er påvist. Feltspat- og kvartskornene er av formene subangular — subrounded. Enkelte større kvarts- og feltspatkorn er meget vel rundet. Bindmassen er finkornet og består til dels av nydannet kvarts og feltspat. I sandstenen finnes også runde klumper (ca. 1 mm i diameter) av basalt med meget hematitt. Orienteringen av plagioklaslistene i disse klumpene tyder ikke på at det er lava-dråper, men bruddstykker av basaltoverflaten. Bergarten med både lokalt stoff og materiale fra sikkert fjerntliggende steder kan ha eolisk opprinnelse, men kan også være vann-transportert.

3) *Kullblende.*

Det er tidligere beskrevet kullblende i rombeporfyren ved Sønsterud (KRISTOFFERSEN 1938). «Mineralet», som av utseende likner antrasit, har sammensetningen: C = 93.2 %, H = 3.7 %, S = 0.4 %, N = 0.2 %, O = 2.5 %. Det finnes her i blærerum og på sprekker sammen med kalkspat og flusspat. Kristoffersen antar at kullblenden utgjør de siste tungt flyktige bestanddeler av en opprinnelig jordolje eller bitumen. Omtrent samtidig ble det beskrevet funn av kullblende sammen med epidot og prehnit i basaltlavaen B_1 ved Semsvik (BUGGE og NEUMANN 1938). Forfatterne av notisen antyder muligheten av at kullstoff-forbindelsen kan skrive seg fra permtidens vegetasjon, men det er også nevnt at den kan stamme fra forbindelser i basaltmagmaet.

Ved Sønsterud er det nå funnet kullblende foruten i rombeporfyr også i de underliggende lag av sandsten og basaltlava. Spektrografisk undersøkelse utført ved Sentralinstituttet for industriell forskning, Blindern, viser at kullblenden er vanadiumholdig. Uran er ikke påvist. At kullblenden på dette sted forekommer både i rombeporfyr, sandsten og basalt, tyder på at den ble dannet etter at rombeporfyren var kommet på plass, og det utelukker for så vidt ikke den tidligere antakelse om et utgangsmateriale i permisk vegetasjon.

Under fortsatt arbeide med kullblende har jeg sett på materiale fra andre beskrevne forekomster av samme mineral. Det gjelder bl.a. Kongsberg (NEUMANN 1944) og Grønnsæter i Hol (REUSCH 1919). I Museets samlinger finnes også prøver fra 6—8 andre steder. Særlig pent er det materialet som jeg etter opplysning fra landbruksskolebestyrer Heldal, kunne samle inn våren 1955 ved Åmot i Modum. Etter det som nå er kjent finnes kullblende en rekke steder i Sydøst-Norge i så vel grunnfjell og kambrosilur som i permiske sedimenter og lavaer. Observasjoner og analysemateriale tilrettelegges nå for en egen artikkel.

4) *Putestruktur og sandstensganger i rombeporfyrlava.*

Grenseforholdene mellom de enkelte strømmene av rombeporfyrlava, liksom de enkelte lavaers utseende og mineralogiske sammensetning, er nå for en stor del kjent, særlig ved Chr. Oftedahl arbeider (OFTEDAHL 1954, HOLTEDAHL og DONS 1955,). På Krokskogen er det f.eks. en 0.3 m tykk agglomerat-konglomeratbenk mellom RP_2 og RP_3; RP_3 er todelt ved en 2 m mektig benk av tuffitisk sandsten; mellom RP_3 og RP_4 er det agglomerat og konglomerat, og mellom RP_4 og RP_5 er det en rød sandstensbenk 0.5—1 m tykk. Rombeporfyrene er trachy-andesitter med SiO_2 innhold ca. 50 %. Pheno--krystallene er antiperthitiske med plagioklas-fase av sammensetning 30—40 % An.

Muligens vil et møysommelig regionalt studium av flytestrukturene innen RP_1 kunne bringe nye opplysninger om hvorledes den ca 150 m tykke lavastrøm har avansert. Det kunne da også være mulig nærmere å lokalisere beliggenheten av de spalter som lavaen vel har flytt ut av. De observerte putestrukturene og sandstensgangene som beskrives nedenfor gir muligens et bidrag til forståelse av hvorledes lavaen var da den fløt ut.

Rombeporfyren RP_1 i veisvingen ovenfor Sønsterud ser på avstand bollet, valket, pute-aktig ut, med uregelmessig avrundete enheter hvis vertikale snittflater er en til flere kvadratmeter, fig. 2 og 3. Veiskjæringen har to vertikale eruptivganger (ikke tatt med på kartskissen, vises heller ikke på fig. 2) som er tydelig yngre og uten forbindelse med putestrukturen. Stort sett danner putene en tilnærmet flattliggende benkning. Det er ingen felles, regelmessig form på «bollene». De fleste er flattrykte og vridd med konveks eller konkav overside. Bolleutviklingen avtar oppad i profilet mot en utvitret horisont. De øverste ca. 20 m av RP_1 er av vanlig forholdsvis «massiv» karakter med steile oppsprekningsflater. Grensen mot RP_2 ses inne i neste veisving. Det er bare spor av sediment på grensen mellom RP_1 og RP_2. På det trykte geologiske kart 1 : 100 000 (BRØGGER—SCHETELIG 1917) er grensen mot RP_2 lagt atskillig lenger nord. Etter å ha passert en forkastning i bekkedalen, hvor den vestre blokk er sunket ca. 50 m i forhold til den østre, treffes pute-utviklingen i RP_1 igjen. Idet veien stiger overleires den av normal RP_1 som står i alle veiskjæringene opp til Homledal (1.5 km), hvor RP_2 overleirer den. Pute-utviklingens øvre begrensningsflate heller mot NE omtrent parallelt med grenseflaten mellom RP_1 og RP_2. Undergrensen av «putesonen» er ikke funnet på grunn av overdekning. Pute-utviklingen er antakelig 30—40 m mektig og når således ikke bunnen av lavastrømmen. Den horisontale utbredelse er lite kjent.

Et nøyere studium viser at bollene er begrenset av lett forvitrende skall, 5—40 cm tykke, bestående av rombeporfyr. I skallene er det en gjennomført orientering av phenokrystallene parallelt med begrensningen av de hardere og derfor utstående rombeporfyr-bollene. Det er ingen knivskarp grense mellom skall og boller. De siste har også utpreget parallell-orientering av sine phenokrystaller i de perifere deler. Blærerom er mest utpreget nær bollenes yttersider. I mange snitt begrenses bollene fullstendig av smuldrende skall, i andre tilfelle bare delvis, idet flere boller henger sammen. På grunn av den forvitrede karakter kan det ikke avgjøres om skallenes grunnmasse har hatt en annen struktur enn bollenes. Det kan tenkes at grunnmassen i skallsonene opprinnelig har vært glass.

Pute-utvikling av den type som rombeporfyren viser er et alminnelig trekk hos basaltiske lavaer (pahoe lava og pillow lava). *En nødvendig betingelse for utvikling av slike valkete og bolleaktige former* *er at lavaen beholder sin lettflytende tilstand gjennom en relativ lang kjølingsperiode og at den blir sterkt viskøs innen et lite temperaturintervall umiddelbart før den stivner helt.*

Studier over pillowlavaer (Lewis 1914) viser at det praktisk talt bare er lavaer av basaltisk sammensetning som størkner på denne måte. Sjelden er slike strukturer observert i så sure lavaer som rombeporfyrer. Lewis hevder at de karakteristiske pære- eller løk-aktige former dannes ved knoppskytning på eller i en størknende lavafront. Ved knoppskytningen vil hvert voksende legeme ha en forbindelseskanal til den helt flytende lavamassen det gikk ut fra. Gjennom kanalen tilføres det stadig materiale under trykk. Størkningshinnen, som ofte er glassaktig, vil da strekkes, i en del tilfelle sprekke — og en ny knopp kan bli dannet. Strukturene inne i bollene vil bli parallelle med den ytre begrensning; det gjelder phenokrystaller, blærerom, osv. En kontraksjon under den videre størkning anses tilstrekkelig for å avsnøre forbindelseskanalene hvorved isolerte pillows blir dannet. Pahoehoe-lava og pillow-lava blir etter dette ved overgangsledd nær beslektet. Med den foreliggende struktur skulle *rombeporfyren her kunne karakteriseres som relativt sur pahoehoe-lava eller pillow-lava.* Bollenes form gir ikke grunnlag for å bedømme hvilken retning lavastrømmen hadde.

Putestrukturen avtar som nevnt oppad mot en utvitret horisont. Det antas at putene er utviklet i en forholdsvis steil fremadskridende lavafront, og at slike strukturer i mindre grad ble utviklet i lavastrømmens aller øverste del og på dennes overflate. Senere kom så en ny strøm og dannet det øverste 20 m tykke lag av mer massiv rombeporfyr. Vi har altså trekk som tyder på at RP$_1$, som inntil nå har vært betraktet som en enkelt strøm, *her er sammensatt av minst to like strømmer.*

Uregelmessige sandstensganger, grå, hvite eller røde, 1 cm—1 m tykke, finnes i skallsonene. En del smale sandstensårer forgrener seg også uregelmessig fra skallsonene inn i bollenes rombeporfyrmasse hvor de ofte skjærer parallellstrukturen i bollene (fig. 5). I flere tilfelle er det således observert 2 mm—1 cm brede ganger som to-deler phenokrystaller.

Lagdeling er observert i flere av gangene (fig. 4). Den følger gang-grensene, og er derfor sjelden horisontal.

Sandstensgangenes kvarts- og feltspatkorn er gjennomgående noe mindre rundet enn tilfelle var i sandstenen over basalten, de er oftest også mindre (fig. 6). Det er funnet enkelte korn av frisk oligoklas, og av pyroxen. Grunnmassen er grøtet. En del slip viser at fintfordelt kalkspat kan utgjøre opptil 50 % av gangene. På lagflater er det ofte tett av glimmerskjell. Hvor lagdeling er synlig viser preparater at det er størrelsen på kornene og mengden av mellom-massen (ves. kalkspat) som gir lagdelingen. For øvrig er sandstensgangene fra sted til sted svært varierende både når det gjelder forholdet mellom mineralkomponentene og forholdet mellom vel rundete korn og uregelmessig begrensete mineralfliser. Enkelte slip viser stor likhet med sandstenslaget over basalt. En del av kornene kan ikke være dannet av lavaens mineraler. De må være tilført fra mer fjerntliggende områder.

Det viste seg at da en først begynte å lete etter ganger eller uregelmessige partier av sandsten, var de slett ikke så sjeldne. De finnes således en rekke steder sydover langs Tyrifjorden. Hittil er de imidlertid bare observert i RP_1. På en del av de stedene hvor sandstensgangene er sett, f.eks. ca. 1 km N for gården Toverud i skjæring langs riksveien Skaret—Sylling er det antydning til puteutvikling i lavaen. Det synes å foreligge flere vesentlig forskjellige muligheter for disse dannelser. 1) Sand kan være tilført ovenfra gjennom sprekker. Som nevnt er det ofte sandholdige sedimenter mellom de overliggende lavastrømmene, hvorfra sandkorn gradvis kunne falle eller bli ført av overflatevann ned i sprekker. En skulle da imidlertid kunne vente at lagdelingen i sandstensgangene var mere horisontal. Når sandstensgangene er særlig hyppige i bollelaget (de finnes sjeldnere i de 20 metrene rombeporfyr over dette) skulle det kunne forklares ved at det her muligens var rikelig med åpne rom som kunne fylles. Andre steder hvor sandsten forekommer som uregelmessige ganger eller partier er rombeporfyren imidlertid så kompakt og homogen at det er vanskelig å tenke seg at det kan ha vært passasjer ovenfra som var tilstrekkelig store til at sandkornene kunne passere. Det er mulig at noen ganger er dannet på denne måte, men stort sett synes den annen dannelsesmåte mer sannsynlig.

2) Sand var til stede da lavaen fløt utover og bollene ble dannet. Lavaen kan således ha rotet opp i et til dels lagdelt sandlag. Det er nærmest en betingelse for pillowlava-utvikling at det er rikelig med fuktighet til stede, enten sterkt fuktig luft, sumpet terreng, eller sjø som lavaen strømmer ut i. Dette siste er det vanligste. RP_1 lavaen

kan da ha strømmet ut i vann hvor det nevnte sandlag over basalten var bunnfeldt, og kan ha rotet opp i dette halvt konsoliderte sediment og inkorporert noe av det under sin videre fremtrengen, omtrent som sneballer tar opp gruslag når de rulles på en grusvei med tynt snedekke. Hvis utbredelsen av sandstensgangene i RP_1 var bedre kjent kunne det tillegges mere betydning at sandstensgangene bare er funnet der hvor det er sandstenslag under RP_1, og det kunne tolkes som en indikasjon på at sandmaterialet var opptatt i lavaen under dennes fremtrengen.

Som en tredje mulighet nevnes at sandlagene kan være avsatt på den fremtrengende lava ved hjelp av vann eller vind.

I vestsiden av Grefsenåsen har Holtedahl beskrevet særegne deformasjons-strukturer, nærmest folder, på grensen mellom sandstenslag (der kvartsitt) og den overliggende rombeporfyrlava RP_1 (HOLTEDAHL 1935, HOLTEDAHL og DONS 1955). Deformasjonen, som har karakter av en mer eller mindre isoklinal foldning, oppbrytning og skyvning, forklarer Holtedahl som dannet under den nærliggende nordmarkitts størkning. Mange ting tyder på at dette er riktig. En annen forklaring, som Holtedahl nevner men avviser som umulig, er at «foldningen» skyldes den flytende lavaens bevegelse over sandlag. Etter å ha sett utviklingen ved Sønsterud kan jeg ikke helt se bort fra at den siste mulighet kanskje kan være riktig.

SUMMARY.

The Sønsterud locality situated at the eastern border of the Krokskogen (Permian) lava area, near Tyrifjorden (see keymap in fig. 1) has often been cited in connection with the interpretation of the geological history of the Oslo Region, e.g. the sub-Permian denudation and the Permian faulting. (KJERULF 1865, BRØGGER 1890 & 1931, RODE 1930). New investigations recently carried out by the author have shown that the locality can throw more light on the history of this region.

1) A small area of basalt found in the Silurian limestone (fig. 1) was at first assumed to represent a feeeding channel for the basalt lava, B_1, nearby. It turned out, however, to be a detached block of basalt in a NNW—SSE running Permian fault zone. The same fault also hides the Permian sediments, (including a quartz conglo-

merate located between the Permian basalt, B_1, and Silurian limestone).

2) In the central eastern part of the Oslo Region there is a bed of quartz sediment, between basalt, B_1 (below) and rhomb porphyry, RP_1 (above). The same sediment was now found in the central western part of the Oslo Region, but it has never been reported from the area between. At Sønsterud where the bed of sandstone is $^1/_2$—1 m thick it covers a red-looking, hematite-rich, weathered surface of basalt. The main mineral in the sandstone is quartz, often with undulating extinction. The grains of feldspar (perthite, oligoclase-andesine, microcline?), and the few grains of garnet observed have the same shape (sub-angular to subrounded) and the same size as quartz (0.1—0.5 mm in cross section). Small rounded pieces derived from the underlying basalt are also found in the sandstone (fig. 7). The composition of the sandstone with both local and foreign material and the shape of the grains might possibly indicate an æolian origin, but transport and sedimentation in water seems more likely.

3) «Coal blend», an antracite-like coal-«mineral» has earlier been reported from the rhomb porphyry at Sønsterud, where it can be found in vesicles and narrow fissures together with calcite and fluorite (Kristoffersen 1938). What is new at this locality is that the coal blend was also found in the underlying beds of sandstone and basalt. Very little is known about the origin of the material. The composition is: $C = 93.2$, $H = 3.7$, $N = 0.2$, $S = 0.4$, $O = 2.5$. New spectrographical investigations have shown that the material contains small amounts of vanadium. During his study, the writer became aware of new and better occurrences of coal blend and also undescribed museum specimens from Precambrian and Cambro-Silurian, as well as Permian areas of south-east Norway. Further investigations have been carried out and the results will be published in a later number of this journal.

4) As most of the rhomb porphyry lava streams with rather constant andesitic composition and with very small variations in thickness cover huge areas, it has been assumed that the viscosity has been low. In the road section at Sønsterud (exact location marked D in fig. 1) the rhomb porphyry shows pillow-like structures (fig. 2 and 3) closely resembling those of true pillow lavas. This should strengthen the former assumption that the relatively acid rhomb porphyry ($SiO_2 =$

50—53 per cent) during its outflow and solidification had physical properties corresponding to those of basaltic lavas.

The thickness of the pillow-lava bed is 30—40 meters as a minimum It most probably does not reach the bottom of the RP_1 lava bed. Upwards the pillow structure gradually disappears as it approaches a now weathered surface, which again is surmounted by a bed, 20 m thick, of normal RP_1. Then follows, without any sedimentary layer in between, the second rhomb porphyry lava, RP_2. The length of time corresponding to the weathered surface is unknown. Together with the pillow structures it indicates that the rhomb porphyry RP_1 at this place is composed of two or more streams of equal mineralogical composition.

Partly stratified sandstone «dykes» occur between, and to some extent also in, the pillows, fig. 4, 5 and 6. The incorporation of sandy material which possibly took place in a body of water may to some extent have favoured the formation of pillows in the advancing lava front.

The sandstone «dykes», according to few and scattered observations, would seem to develop only in RP_1, and to be limited to areas where a bed of standstone is found at the base of RP_1. This could indicate that the sandy material in «dykes» was picked up by the lava from below. In other places with sandstone «dykes» the RP_1 is very massiv and homogeneous; this seems to exclude the possibility that the sandy material came from one of the sedimentary layers which separate higher RP-streams.

The local occurrence of «folded» sandstone (quartzite) under rhomb porphyry RP_1 in Grefsenåsen (Holtedahl 1931) should be mentioned. Holtedahl does not think that the folded structures were produced by the lava, while moving along above the sand beds. His interpretation is that the magmatic mass (now a nordmarkite situated close to the folds) during a downward movement produced a dragging effect giving rise to folding of isoclinal character, fracturing and thrusting. The present author, after having seen the locality in Grefsenåsen several times and now that of Sønsterud, can not definitely rule out the possibility that the folds do represent primary features, produced by the moving lava.

Universitetets Mineralogisk-Geologiske Museum.
Oslo, januar 1956.

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PLATE I

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Fig. 2. Putestrukturer i veiskjæring nær Sønsterud, Tyrifjorden.

Pillow-like structures in roadcut near Sønsterud, Tyrifjord lake, W of Oslo.

Fig. 3. Puter av rombeporfyr med lett forvitrende skall av rombeporfyr.

Pillows of rhomb porphyry with easily weathering shells of rhomb porphyry. (Originally with groundmass of glas?)

Fig. 4. Lagdelt sandstensgang mellom rombeporfyrlava-puter.

Stratified sandstone dyke between pillows of rhomb porphyry lava.

Fig. 5. Sandstensgang i rombeporfyr-pute (mørkt bånd på skrå nedad fra fyrstikkeskens nedre venstre hjørne).

Sandstone dyke in pillow of rhomb porphyry (dark band from lower left hand corner of match-box).

Fig. 6. Tynnslip av sandstensgang i rombeporfyr-pute. Det mørke nedre venstre hjørne er en phenokrystall i lavaen, x nic. 30 x.

Thin section of sandstone dyke in pillow of rhomb porphyry. Dark corner lower left is a phenocryst in the lava. x nic. 30 x.

Fig. 7. Tynnslip av sandstenen som ligger mellom basalt B_1 og rombeporfyr RP_1. Et stykke av basalten ses i venstre halvdel av bildet. x nic. 30x.

Thin section of the sandstone found between basalt B_1 and rhomb porphyry RP_1. Note especially the piece of basalt, left-centre. x nic. 30 x.

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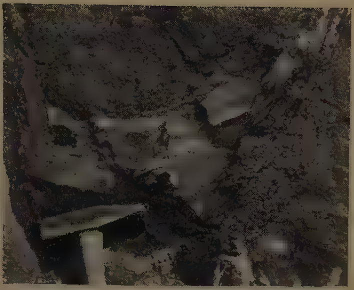

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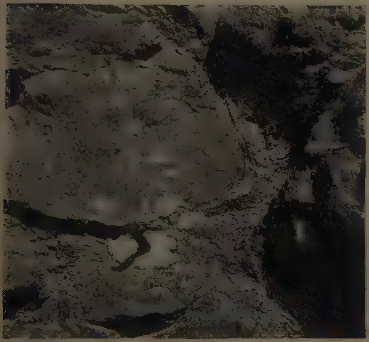

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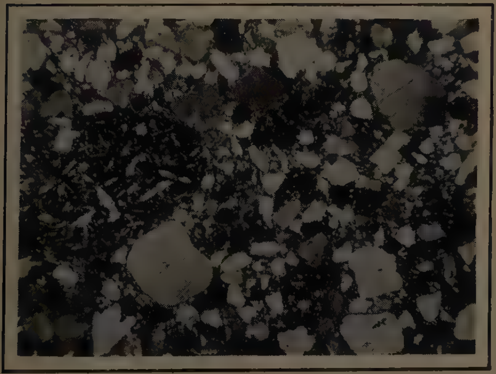

7

ET NYTT FUNN AV MAMMUTSTØTTANN FRA NORGE

A new mammoth tusk discovered in Norway.

AV

ANATOL HEINTZ.

Abstract. In the autumn of 1955, two fragments of mammoth tusk were discovered at Skreia, Toten (S. Norway) (Pl. I). They lay ca. $1^1/_2$ m below the level of the main street in Skreia, about 1 m in the ground moraine. The fragments fit well into each other, (Pl. I, 1) and together they form a piece of a mammoth tusk ca. 63 cm long and 23,5 cm around the thickest part and 19 cm around the thinnest end. It is thus likely that the tusk originally was comparatively small — about 150 – 165 cm long — and belonged to a female mammoth (Text fig. 1). It is the 8th mammoth tooth found in Norway (Text fig. 2) (5 grinding teeth and 3 tusks. See HEINTZ, A. 1955).

I slutten av september 1955 ble det i Skreia på Toten funnet et stort fragment av en mammutstøttann. Under grøftegraving for telegrafverket i Skreias hovedgate, like ved meieriet, støtte arbeideren OLAF KRISTIANSEN på en sylinderformet, mørkfarget gjenstand, som han først tok for en rot. Men ved nærmere undersøkelse kunne han konstatere at det var et ben eller en tann. Det ble sendt bud etter konservator ved Toten Museum, magister SIVESIND, som straks fikk mistanke om at det dreide seg om et nytt mammutfunn. Da tannen kom til Paleontologisk Museum, kunne man bare konstatere at SIVESIND hadde rett — den funne gjenstad var et bruddstykke av en velbevart mammutstøttann, det åttende funn gjort i Norge.

Dagen etter reiste en del av museets folk, sammen med mag. SIVESIND, til Skreia for å undersøke forholdene. Arbeider KRISTIANSEN mente nemlig at han også på et tidligere tidspunkt hadde gravd frem en lignende, men mindre tannbit, og trodde at denne kunne ligge i jordhaugene ved grøften. Da vi kom til Skreia, var grøften ennå delvis åpen. KRISTIANSEN renset finnestedet slik at man kunne se hvor tannen lå. Grøften var ca. 2 m dyp. Den øverste halve meteren representerte resent fyll som besto av stein, mursteinsbiter, sand, jord, grus osv.. Under dette lag begynte et tettpakket morenemateriale, bestående av leire, sand, grus og steiner av forskjellig størrelse. Materialet var usortert og ikke på noen måte lagdelt. Tannen lå ca. 1 m inni morenen — altså $1^1/_2$ m under jordens overflate og ca. $^1/_2$ m fra bunnen av grøften. På det sted tannen lå, kunne man i grøftesiden se et brunfarget sandparti sammenkittet med utfelt jernoksyd. Arbeiderne fortalte at jorden rundt tannen var lysere i farge enn ellers i grøften. Tannen lå nesten horisontalt, nærmest på tvers av grøften. Stykkene lå like ved hverandre, det ene noe mere skrånende nedover enn det andre.

Det lyktes oss ikke å finne den tredje biten av tannen i jorden som var gravd ut fra grøften. Sannsynligvis har ikke den gjenstand KRISTIANSEN har lagt merke til vært et stykke av tannen, men en stein, en leirklump eller lignende.

Som nevnt tidligere er tannen forholdsvis bra bevart. Det foreligger to biter — den ene på ca. 33 cm, den andre på ca. 30 cm. Den største og tykkeste biten (Pl. I, 4, øverst) er temmelig mørkebrun-gul av farge, glatt og tett. Den ene enden er brutt av noe på skrå og er vel avrundet. I sprekkene ligger en del leire og jordpartikler sammenkittet med jernoksyd til sort-brune klumper. Den andre enden er mer ujevn, bruddet går her rett på tvers, og overflaten er ikke nevnverdig avrundet, men uten noen friske brudd. Stykkets omkrets er størst, ca. 10—12 cm fra den avrundede ende og måler her 23,5 cm. Tannen avtar i tykkelse mot begge ender hvor omkretsen ikke er større enn 23 cm.

Det andre stykket (Pl. I, 4, nederst) er lysere i farge og meget dårligere bevart, mere sprøtt og oppsprukket, og overflatelaget er løst og faller lett av. Stykket er tverravkuttet i begge ender. Tverrsnittet ved den smaleste enden er av en brun-grå farge, sterkt forvitret og radiært oppsprukket. Tverrsnittet av den brede enden virker meget friskere, dentinet er gråhvitt og oppsprukket, og man ser en mengde planterøtter som har presset seg inni sprekker og mellom dentinlagene. (Pl. I, 2, 3, c). Hele stykket er, som nevnt, 30 cm langt, og omkretsen av den bredeste enden er ca. 22 cm og av den smaleste ca. 19 cm. Et lite stykke av tannens overflateskikt, som stikker ut bakover ved den bredeste enden, passer inn i en liten fordypning i en av endene i det lengste stykket (Pl. I, 1, a—b), slik at det er sikkert at begge stykkene er deler av én og samme tann som er brukket over på midten. Det merkelige er at berøringsflaten mellom stykkene er så liten, bare ca. 3,5 cm lang (Pl. I, 1, 2, 3, a—b) og knapt 0,5 cm bred. (Pl. I, 3, a—b). Men bruddflatene på begge stykkene passer så utmerket sammen, og hele tannens bøyning og fasong får et så naturlig utseende, at det er meget vanskelig å tro at det bare foreligger en tilfeldig likhet i bruddflatene. Da tannstykkene ble funnet så nær hverandre, må man anta at tannen gikk i stykker ikke langt fra det sted hvor den ble funnet. På dette tyder også den omstendighet at bruddflatene som vender mot hverandre, ikke er det spor avrundet eller slitt, men er svært ujevne. (Pl. I. 3). At bruddstykkene er så forskjellige både når det gjelder oppbevaringstilstand og farge, er også ganske merkelig. Man må anta at det ene lå høyere oppe enn det andre, og således er blitt mere utsatt for påvirkning av rinnende vann og planterøtter. Som nevnt er det lysere, kortere stykket meget mer porøst, (Pl. I, 4, nederst) og på mange steder finner man planterøtter presset mellom dentinlagene. Det største stykket er meget mere massivt, mørkere (Pl. I, 4 øverst), og planterøtter kan ikke påvises. Kanskje lå det under grunnvannspeilet, og er blitt mere gjennomtrengt av jernholdig vann, som til en viss grad har impregnert det med jernoksyd.

På begge stykkene ser man tydelig spor etter de undersøkelser som arbeiderne har foretatt for å finne ut hva det var for slags gjenstand de hadde kommet over. På et par steder er stykker av tannen spikket vekk med kniv — til dels er det gjort ganske dype innhakk. Dessuten er det på to steder på det største stykket, og på et sted på det minste, tydelige spor etter en firkantet hakkespiss, som man har slått tannen med. Særlig er det minste stykket tydelig beskadiget, da det er meget løsere og bløtere.

Legger man de to bitene sammen slik at de berører hverandre, får man et tannstykke på ca. 63 cm lengde. Det er således den lengste mammut støttannstykke vi kjenner fra Norge.

Hvor stor kunne så tannen opprinnelig ha vært? Hos mammuten er tannen tykkest der hvor den stikker ut av kjeven. Omtrent 30—40 cm av tannen ligger inne i tannalveolen. I denne delen av tannen er det koniske, forholdsvis dype pulpahullet utviklet. I Totentannen er

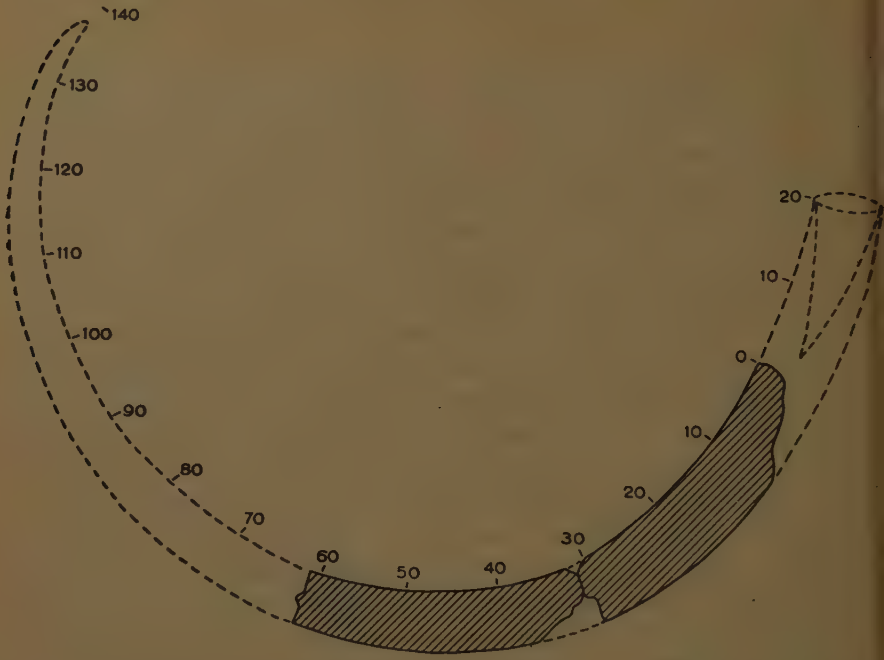

Fig. 1. Rekonstruksjon av støttannen fra Toten. De skraverte deler — de to stykker som er funnet.
Reconstruction of the tusk from Toten. The hatched parts — the two discovered pieces.

ingen spor av pulpahullet bevart. Enden med bruddflaten som passer inn i det andre stykket, må selvsagt være den forreste, og den andre den bakerste. Den bredeste del av tannen må være det parti som akkurat stakk ut fra kraniet. Fra den bredeste delen til den bakre enden av tannen er det ca. 10—15 cm. Vi må således anta at tannen var opprinnelig ca. 20—25 cm lenger bakover, og at pulpahullet lå akkurat inne i den avbrukkede delen. Det er i og for seg ganske rimelig at nettopp denne delen av tannen er blitt borte. Her er tannens vegger tynne og kan lett knuses.

Tegner man de to bitene som ett sammenhengende stykke på et papir, får man et jevnt krumbøyd tannfragment, som avtar moderat i tykkelse mot den ene enden, og en tanke mot den andre. Forsøker man så å rekonstruere den manglende forreste delen ved å tegne fortsettelsen av tannen, krummet på samme måte som den foreliggende del, og smalnende av omtrent som de to stykkene vi har, får man en tann på omtrent 130—140 cm lengde. Føyer man så til de ca. 20—25 cm som er brutt av den bakerste enden, får man en tann som er mellom 150 og 165 cm lang. (Tekst fig. 1). Til å være en mammutstøttann er den således ikke stor. I Paleontologisk Museum har vi bare to som er mindre — den ene 21 cm i omkrets på det tykkeste og 155 cm lang, og den andre 29 cm i omkrets og bare 145 cm lang. Alle de andre tennene oppbevart i Paleontologisk Museum, Oslo er til dels betydelig større — nemlig 200 cm, 225 cm, 250 cm og endelig et bruddstykke av en stor tann som må ha vært over 3 m lang. Også PFIZENMAYER (1926) oppgir en del målinger av støttenner. En av de minste han nevner var 25 cm i omkrets på det bredeste, 185 cm lang og sterkt krumbøyd. Ellers nevner han tenner på 279, 367 og endelig en på hele 416 cm.

Når det gjelder dimensjonene minner således tannen fra Toten mest om den nest minste tannen vi har på Museet, nemlig den med en omkrets på 21 cm og lengde på 155 cm, og på den minste tannen som PFIZENMAYER nevner, med en omkrets på 25 cm og lengde på 185 cm. Tannen fra Toten er imidlertid sterkere krummet enn tannen i Paleontologisk Museum, men er rettere enn PFITZENMAYERS tann. Man pleier å betrakte de små og slanke tenner som tilhørende hunndyrene. Det er derfor sannsynlig at støttannen fra Skreia på Toten har tilhørt en voksen hunn-mammut.

Finnestedet for den nye støttannen ligger midt mellom to steder hvor det tidligere er gjort lignende funn, nemlig Fåvang og Jessheim — dog betydelig nærmere det siste sted (Tekst fig. 2). Støttennene både fra Jessheim og Fåvang lå i mer eller mindre klart lagdelte sand- og grusmasser (HOLTEDAHL 1931, 1953, HEINTZ 1945). Tannen fra Skreia er den eneste som er funnet i en virkelig typisk bunnmorene. Den er altså blitt transportert sammen med annet materiale fra høyereliggende strøk ved isens fremrykking sørover, for så endelig å bli liggende på det forholdsvis jevne området omkring Mjøsa. Det merkelige er at den har unngått å bli fullstendig knust.

Det er kanskje også av en viss interesse å fremheve at det ser ut til at de mindre og tyngre mammut-kinntenner hovedsakelig er blitt liggende i høyere strøk hos oss, nærmere de steder hvor mammuten virkelig har levd (Vågå, Otta, Dovre), mens de relativt lettere og større støttennene er blitt transportert lengre ut i periferien (Tekst fig. 2) (Heintz 1951).

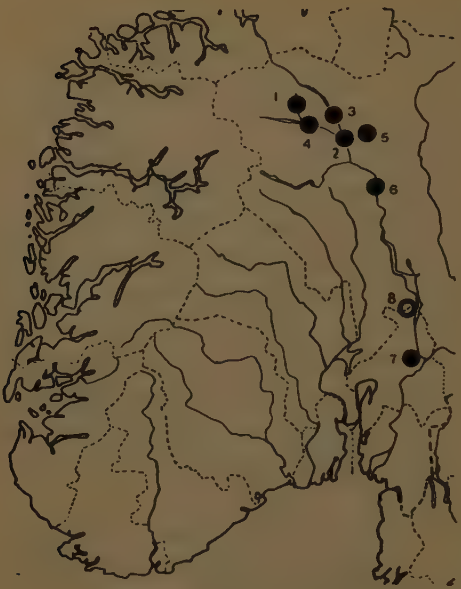

Fig. 2. Kart over mammut-funn i Norge. 1 — Skarvangen, 2 — Otta, 3 — Dovre, 4 — Vågå, 5 — Ula, 6 — Fåvang, 7 — Jessheim, og 8 — det nye funn fra Skreia, Toten. Funnene fra 1 til 5 — kinntenner, fra 6 til 8 støttenner.

Map, showing the mammoth finds from Norway. 1—Skarvangen, 2—Otta, 3—Dovre, 4—Vågå, 5—Ula, 6—Fåvang, 7—Jessheim, 8—the new find from Skreia; Toten. Finds 1—5-grinding teeth, 6—8 tusks.

I forbindelse med diskusjonen om mammutens forekomst i Skandinavia, har man (Heintz 1945, 1954) fremhevet at alt tyder på at mammuten levde i Skandinavia under den siste mellomistid, og var helt utdødd i postglacial tid. Etter min mening bekrefter også det nye funn denne antagelse. Hvis mammuten levde i Norge etter den siste istid, ville det være utelukket at støttannen kunne bli funnet i bunnmorenene fra siste.

Imidlertid vil jeg her fremheve at etter undersøkelser som er publisert i Russland av E. D. Zaklinskaja (1954) ser det ut til at mammuten levde i all fall i Nord Taimur (Sibir), like før den varme postglaciale tid — en tid som noenlunde tilsvarer vår Tapes-tid. Forfatteren diskuterer ikke generelt hvorvidt også andre mammutfunn fra Sibir stammer fra et så pass sent tidspunkt, og nevner heller ikke noe om eventuelle postglaciale funn fra den nordlige delen av europeisk Russland. Her er det også av interesse å nevne at i motsetning til Tichomirov og Kuprijanova (1954, se også Heintz 1955), mener Zaklinskaja at i all fall Taimur-mammuten levde i tundrastrøk langt nord for skoggrensen.

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Manuskript mottatt 16. desember 1955.

Trykt juni 1956.

PLATE 1

Mammut støttann fra Skreia, Toten (Foto B. Mauritz).
Mammoth tusk from Skreia, Toten.

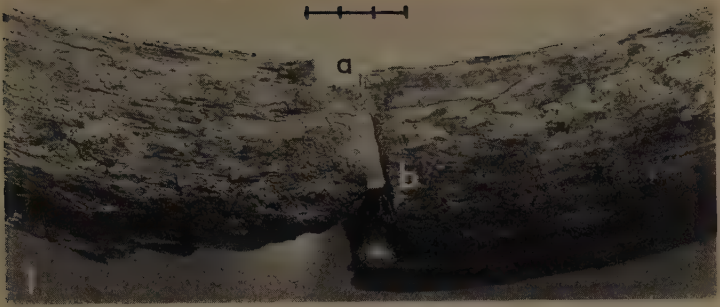
1. De to stykkene i kontakt med hinannen.
Two pieces in contact with each other.

2. Den bakerste del av forreste stykke, som viser kontakt-flaten (b-a) sett innenfra. Ved c- rot-trevler som presser seg inn i sprekkene. (Samme forstørrelse som 1).
The hind part of the frontpiece, showing contact-surface (b—a), from inside. Near c—plant-roots in the dentine cracks. (Same emlargement as 1).

3. Bruddflate av forreste stykke, som viser kontaktflaten (a-b) og rottrevler som presser seg mellom den oppsprukne dentin. (c). (Samme forstørrelse som 1.)
Fracture-surface of the front piece, showing contact-surface (a—b) and plant-roots in the dentine-cracks (c) (same enlargement as 1).

4. Begge stykkene av støttannen ved siden av hinannen. Det bakerste, tykkeste stykke øverst, det forreste, tynneste og mest forvitrede, nederst. a—b —kontaktflaten.
Both pieces of tusk side by side. The hind-thickest piece-above, front—thinner dnd most decomposed—below. a—b contact-surface.

PLATE I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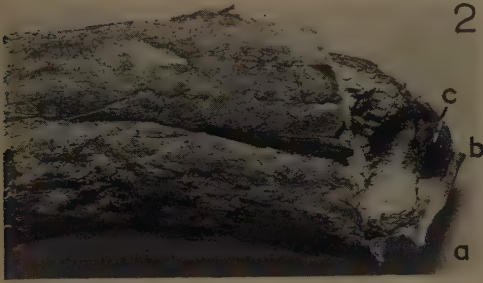
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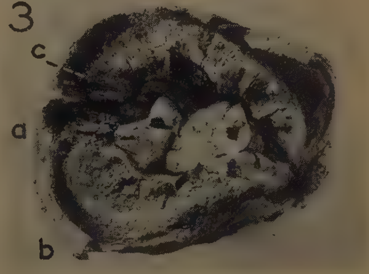
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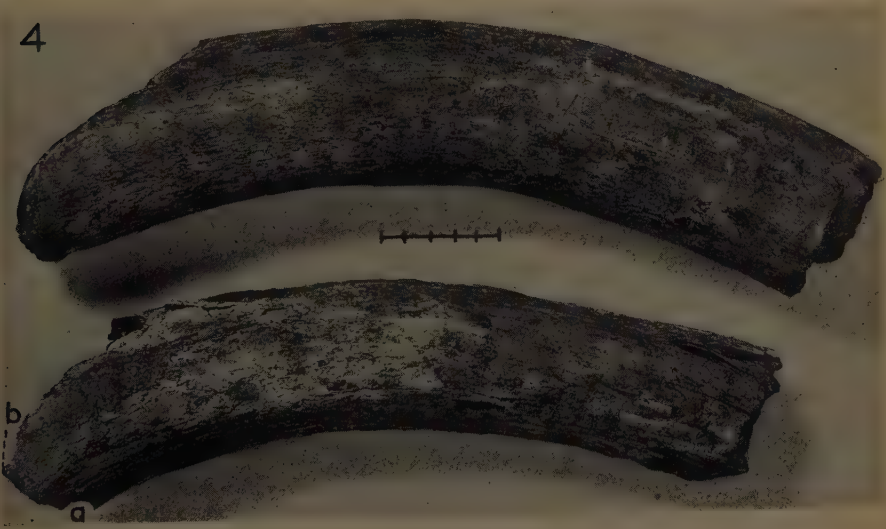
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NORSK GEOLOGISK TIDSSKRIFT 36

SURNADALSSYNKLINALEN

The Surnadal Syncline, Central Norway.

AV

IVAR HERNES

INNHOLD

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Abstract. The Surnadal syncline of the Trondhjem Region is situated in the western part of Central Norway. The geological map, Figs. 2 a and b, shows the western section of this syncline.

The present paper provides a brief description of the main stratigraphical, petrographical and tectonical features of the investigated area. The following groups are described: The Eo-Cambrian Tingvoll Group, the Cambrian — low Lower Ordovician Røros Group and the Lower Ordovician Bymark—Støren Group.

The Surnadal syncline present in the Stangvik—Hamnesfjord—Surnadalsfjord district corresponds to the Molde—Tingvoll syncline (HERNES 1955, 1956). The geological section, Fig. 3, shows that the Surnadal syncline forms part of a larger tectonical unit — an overturned fold with an essentially horizontal axial plane.

FORORD

Feltarbeidet for denne avhandling ble utført sommeren 1955, og bekostet av Universitetets forskningsfond, Bergen. Bearbeidelsen av det innsamlete materiale er utført ved Geologisk institutt, Universitetet i Bergen.

Frk. ELLEN IRGENS har tegnet kartene. Preparant M. SØGNEN har laget tynnslipene.

Jeg vil takke for all hjelp.

Geologisk institutt, Universitetet i Bergen, november 1955.

Innledning.

Det undersøkte område ligger i den vestlige del av Midt-Norge. Oversiktskartet, fig. 1, viser beliggenheten av det kartlagte felt.

Surnadalssynklinalen, en vestlig flik av Trondhjemsfeltet, er besøkt av en rekke geologer, og senest beskrevet av STRAND (1953). I sin avhandling gir Strand en oversikt over tidligere undersøkelser i Surnadalssynklinalen. I samme arbeid skriver Strand om feltets geologi (s. 104): «Concerning the stratigraphy and tectonics of the Surnadal sediments little or nothing can be said until the area has been mapped in detail.»

Det er fra gammel tid kjent at trondhjemsskifrene i Surnadalssynklinalen er en direkte vestlig fortsettelse av tilsvarende skifre i Løkkenfeltet og Hølonda—Horgfeltet. Her er de stratigrafiske og tektoniske forhold klarlagt gjennom undersøkelser av TØRNEBOHM (1896), C. W. CARSTENS (1920, 1951, se også H. CARSTENS 1954 med geologisk kart av C. W. CARSTENS), og TH. VOGT (1945). Det synes meg derfor naturlig å forsøke å løse Surnadalssynklinalens stratigrafiske og tektoniske forhold ved hjelp av disse undersøkelser.

En støtte for dette syn er at trondhjemsskifrene ved Molde viser tilsvarende geologiske forhold som skifrene i det vestre Trondhjemsfelt. Trondhjemsskifrene ved Molde inngår i Molde—Tingvollsynklinalen, som danner en direkte vestlig fortsettelse av Surnadalssynklinalen (HERNES 1955, 1956).

Trondhjemsskifrene i Surnadalssynklinalen og i Molde—Tingvollsynklinalen er foldet ned i gneiser som tilhører det vestlige gneisområdet i Midt-Norge. Allerede TÖRNEBOHM (1896) skiller i dette område ut bergarter som han henregner til Sevegruppen. Videre kan nevnes undersøkelser av C. W. CARSTENS (1924). Senere har en rekke geologer arbeidet med tilsvarende problemer.

Tingvollgruppen i Molde—Tingvollsynklinalen oppfattes som en eokambrisk avdeling. Trondhjemsskifrene ved Molde hviler på Ting-

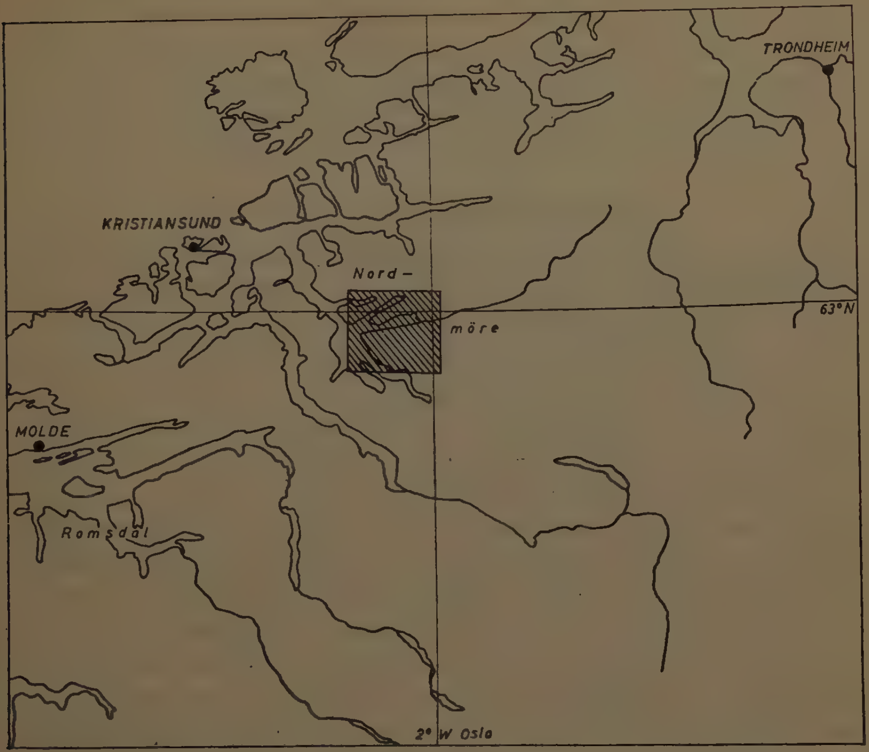

Fig. 1. Det skraverte felt viser beliggenheten av det geologiske kart, fig. 2a og b.
The hatched square shows the position of the geological map, Figs. 2a and b.

vollgruppen, som igjen hviler på homogene gneiser. En av hensiktene med dette arbeide er å studere Tingvollgruppens fortsettelse i Surnadalssynklinalen.

Det geologiske kart, fig. 2a og b, viser den vestlige del av Surnadalssynklinalen. Kartet grenser i vest til Molde—Kristiansundskartet (HERNES 1956). Et geologisk profil, fig. 3, viser hvordan jeg forestiller meg feltets oppbygning.

Ved min undersøkelse har jeg lagt hovedvekten på å oppnå en stratigrafisk-tektonisk oversikt over feltet. Vi har dog her innen et begrenset og lett tilgjengelig område et geologisk meget interessant felt. Når vi engang får moderne topografiske karter innbyr feltet til detaljundersøkelser.

I den følgende beskrivelse har jeg funnet det naturlig å trekke en rekke sammenlikninger mellom Surnadalssynklinalen og Molde—Tingvollsynklinalen. Jeg har videre funnet det overflødig for hver enkelt sammenlikning å henvise til mine to arbeider hvor Molde—Tingvollsynklinalen er beskrevet (HERNES 1955, 1956).

Stratigrafisk-tektonisk oversikt.

Bunnen i Surnadalssynklinalen dannes av homogene gneiser. Over disse er det skilt ut tre avdelinger. Regnet nedenfra har vi Tingvollgruppen, Rørosgruppen og Bymark—Størengruppen. De to siste grupper består av trondhjemsskifre.

Denne stratigrafi, som helt stemmer med forholdene i Molde—Tingvollsynklinalen, ses ved Stangvikfjorden og mellom Hamnesfjord og Surnadalsfjord.

Avdelingene danner en synklinal med en meget flat ombøyning. Dette stemmer også med forholdene i Molde—Tingvollsynklinalen, hvor ombøyningen vider seg ut og blir flatere mot øst. Synklinalens strøkretning er øst—nordøst. I den vestlige del faller foldningsaksen østover. I den østlige del av det undersøkte område faller foldningsaksen mot vest, slik at vi får en depresjon ved Sjøasætervatn.

Mot syd går synklinalen over i en antiklinal, som også har en meget flat ombøyning. Antiklinalen kan studeres ved Stangvikfjorden. Foldningsaksen har her østlig fall. Både de homogene gneiser, Tingvollgruppen og Rørosgruppen er utviklet, mens Bymark—Størengruppen kiler ut mot syd.

Etter rekognoserende undersøkelser syd for Molde—Tingvollsynklinalen ser det ut til at antiklinalen fortsetter vestover, stadig med foldningsakse som faller øst, og at antiklinalen er et meget fremtredende trekk i feltets tektonikk.

De stratigrafiske forhold innen det kartlagte område kompliseres ved at avdelingene gjentas videre oppover i invertert rekkefølge. Over Bymark—Størengruppen ses igjen Rørosgruppen, Tingvollgruppen og homogene gneiser. Både Rørosgruppen og Tingvollgruppen er rikt utviklet i fjellpartiet syd for Surnadalsfjord.

Tektonisk må inversjonen tolkes som en overfoldning; og hele feltet danner tilsammen en stor liggende fold, med ombøyning mot syd, og åpning mot nord, se fig. 3. Den beskrevne synklinal og antiklinal danner den nedre del av folden.

Etter dette blir den synlige del av Surnadalssynklinalen i den østlige del av det kartlagte område, åpningen mellom nordsiden av den egentlige synklinal og den overfoldete del. Rekognoserende undersøkelser videre østover, f.eks. ved Honstad, viser at de tektoniske forhold her er tilsvarende.

Bymark-Størengruppen.

En sone med grønnskifer kan følges fra Surnadalssynklinalens ombøyning ved Stangvik østover langs nordsiden av Surndalsfjorden. Grønnskiferen er en sterkt grønn, skifrig bergart. En alminnelig grønn hornblende er det dominerende mineral. Ellers ses plagioklas, epidot, klorit, kvarts, svovelkis og kalkspat.

Inn for bunnen av Surnadalsfjorden, på nordsiden, ses en liten svovelkisforekomst i grønnskiferdraget. Forekomsten er nr. 79, Bævre forekomst, i Foslies oversikt (FOSLIE 1925).

En sone med kalkstein følger grønnskiferdraget fra Stangvik og østover. Inn for bunnen av Surnadalsfjorden har kalksteinen tildels steilere, til dels samme og til dels flatere fall enn dalsidens helning. Et større parti av dalsiden er derfor her dekket med kalkstein. For å markere hva som utgjør kalksteinsonens heng og ligg av grønnskiferdraget, peker grønnskifertegnet i hver sin retning over og under kalksteinen. Den ovenfor nevnte svovelkisforekomst ligger således i grønnskiferen under kalksteinen.

Kalksteinen er overveiende hvit, helt underordnet sees grålige partier. En svak rødlig tone er også iakttatt.

Tre større brudd er anlagt i kalksteinen nord for Surnadalsfjorden. Fra vest mot øst ligger Årnes Kalkstensbrudd, Sjøflot Kalksteinsgruve og Glærum Kalksteingruve. Produksjonen var i 1953 henholdsvis 19 222 tonn, 28 425 tonn og 71 433 tonn kalkstein. $CaCO_3$-innholdet var 97—98 %. (AASGAARD 1955).

Grønnskiferdraget er en typisk utvikling av Bymark—Størengruppen. Draget ser videre ut til å være overveiende omdannete lavaer, og bare i mindre utstrekning omdannete tuffer og tuffiter.

Rørosgruppen.

Av den stratigrafisk-tektoniske oversikt fremgår at Rørosgruppen ses både under og over Bymark—Størengruppen.

Hovedbergarten i den utskilte Rørosgruppe er glimmerskifer.

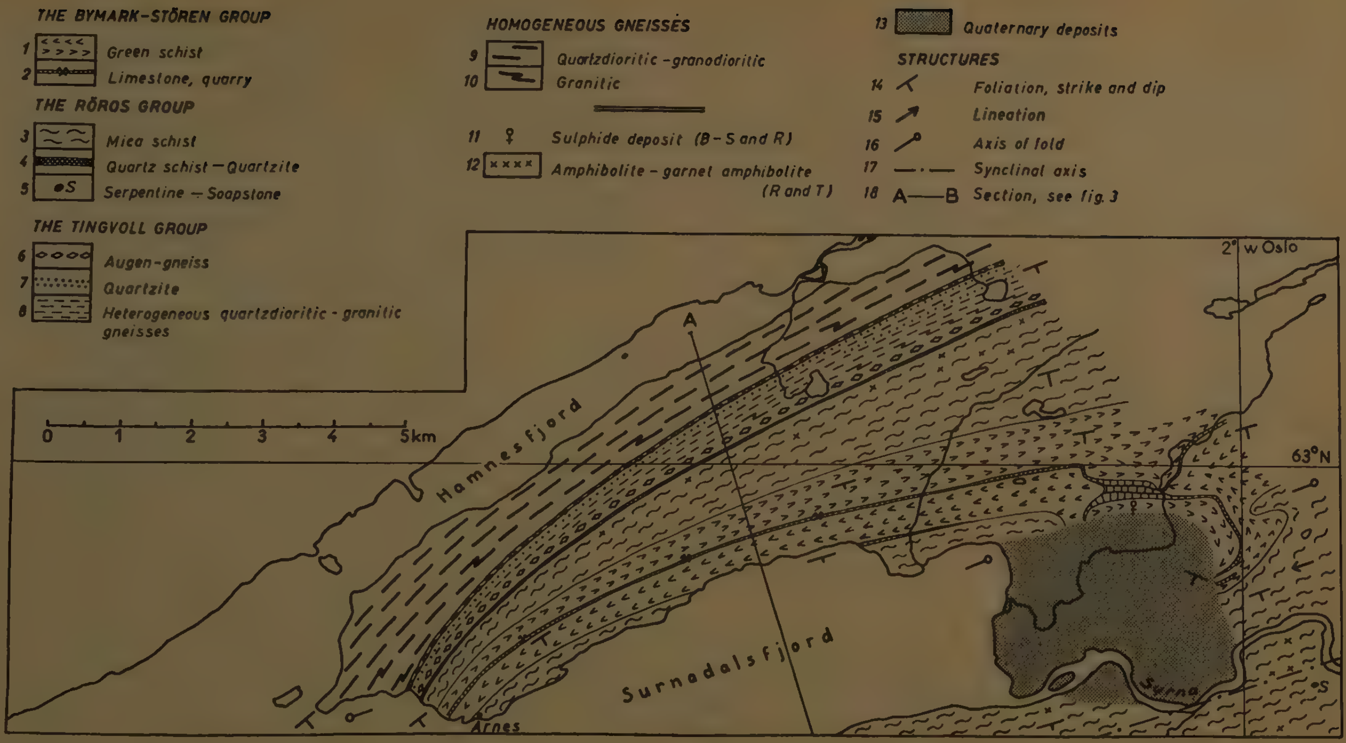

Fig. 2a. Geologisk kart over den nordvestlige del av Surnadalssynklinalen. Tegnforklaring se fig. 3.
Geological map of the north-western part of the Surnadal syncline.

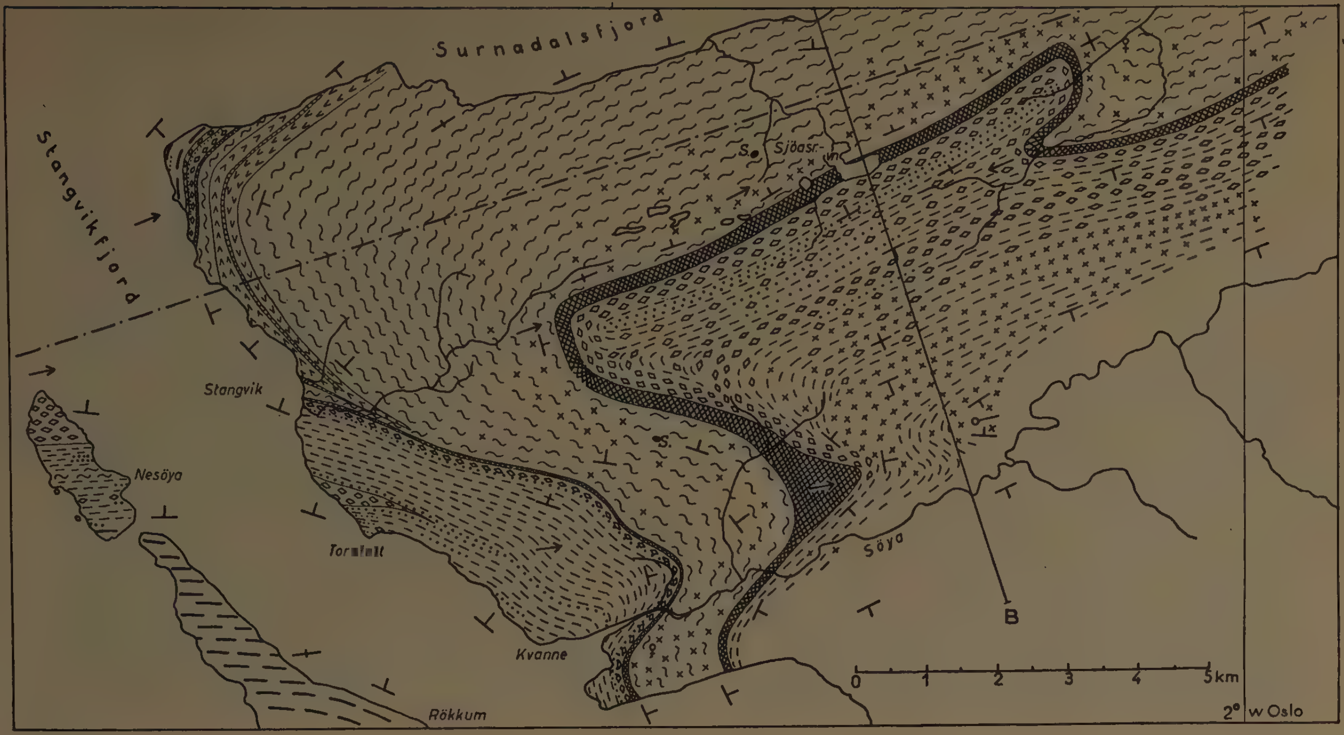

Fig. 2b. Geologisk kart over den sydvestlige del av Surnadalssynklinalen. Tegnforklaring se fig. 3.
Geological map of the south-western part of the Surnadal syncline. Legend see Fig. 2a.

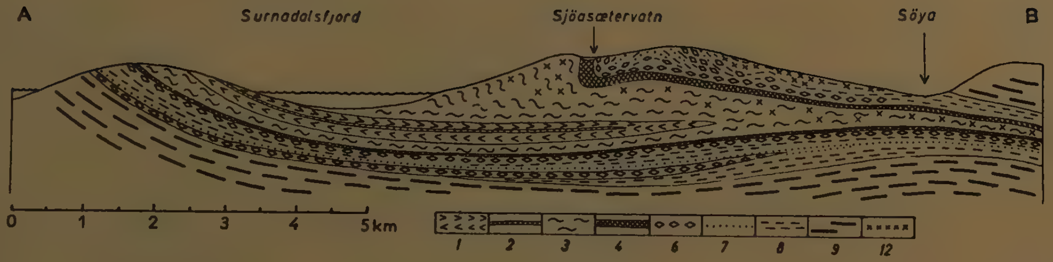

Fig. 3. Geologisk profil fra Hamnesfjord til Søya.
Geological section from Hamnesfjord to the river Søya. Legend see Fig. 2a.

Tegnforklaring til fig. 2a og b og 3. Bymark—Størengruppen: 1. Grønnskifer. 2. Kalkstein, brudd. Rørosgruppen: 3. Glimmerskifer. 4. Kvartsskifer—kvartsit. 5. Serpentin—kleberstein. Tingvollgruppen: 6. Øyegneis. 7. Kvartsit. 8. Heterogene kvartsdioritiske-granitiske gneiser. Homogene gneiser: 9. Kvartsdioritiske-granodioritiske gneiser. 10. Granitisk gneis. — 11. Kisforekomster (Bymark—Støren og Røros). 12. Amfibolit-granatamfibolit (Røros og Tingvoll). — 13. Løse avleiringer. Struktur: 14. Foliasjon, strøk og fall. 15. Lineasjon. 16. Foldningsakse. 17. Synklinalakse. 18. Profil.

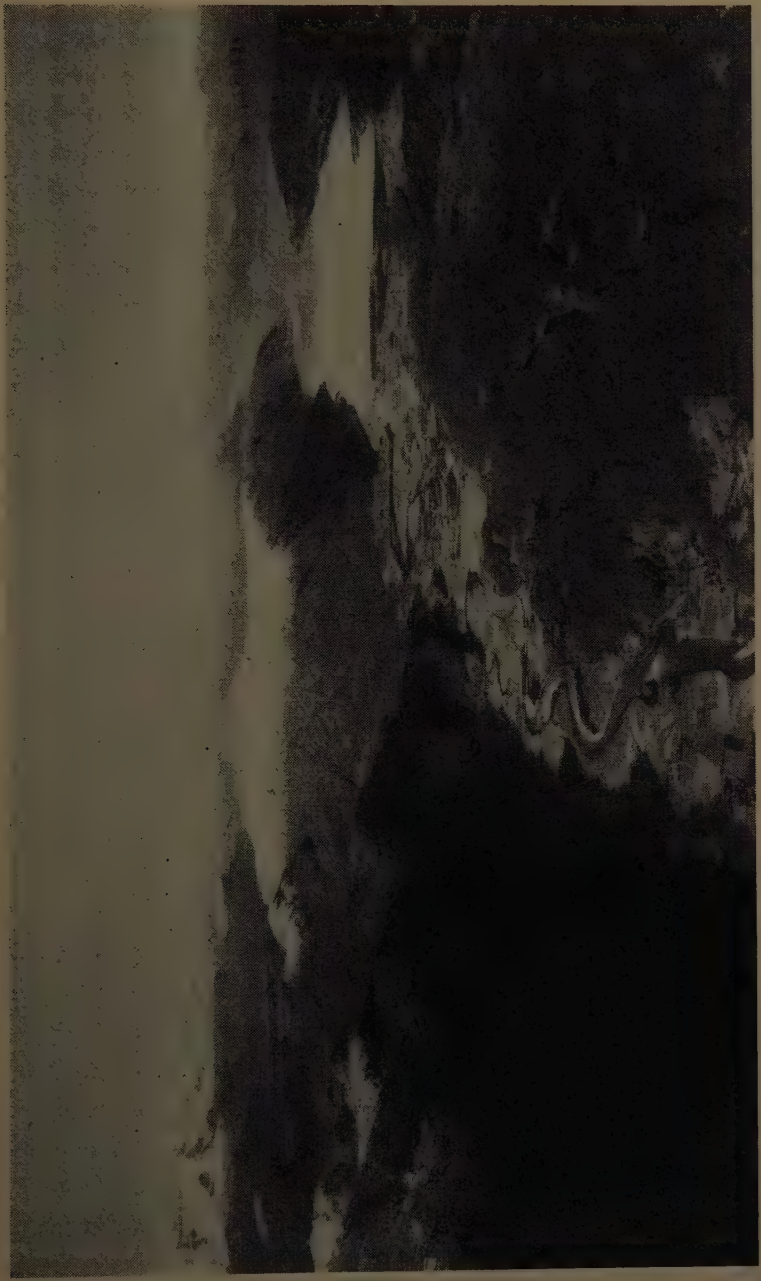

Fig. 4. Surnadalen og Surnadalsfjorden. Fot. Widerøe.

The Surnadal district with the river Surna and the Surnadalsfjord.

Dens hovedmineraler er kvarts, oligoklas og biotit. Biotitens pleokroisme er lys gul — rødbrun. Skiferen er som regel granatførende. Ellers ses epidot, klorit, flogopit, muskovit, sericit, hornblende, staurolit, kis, jernerts, turmalin, apatit og kalkspat.

Strands analyse nr. 1 er av glimmerskifer fra Rørosgruppen tatt under Bymark—Størengruppen i Stangvik. Strands analyse nr. 2 er av glimmerskifer fra Rørosgruppen tatt over Bymark—Størengruppen nord for bunnen av Surnadalsfjorden. Strands analyse nr. 4 er av glimmerskifer fra Rørosgruppen også tatt over Bymark—Størengruppen, men på sydsiden inn for bunnen av Surnadalsfjorden, (STRAND 1953).

Langs eller nær ved grensen mot Bymark—Størengruppen ses tildels en smal sone med kalkstein. Kalkstein er også iakttatt inne i grønnskiferen nær grensen. Glimmerskiferen ved grensen viser tildels en meget kvartsrik utvikling.

I Rørosgruppen, og spesielt i dens stratigrafisk undre del mot Tingvollgruppen, opptrer tallrike små og større forekomster av amfibolit-granatamfibolit. Disse forekomster er spesielt fremtredende i fjellpartiet syd for Surnadalsfjorden og øst for Kvanne.

Både i felten og mikroskopisk atskiller disse amfibolit-granatamfiboliter seg sterkt fra Bymark—Størengruppens grønnskifre. I alminnelighet er de både mer massive og mørkere enn grønnskifrene.

Hovedmineralene er grønn hornblende og oligoklas. Amfiboliten er ofte granatførende. Ellers ses epidot, klorit, biotit, kvarts, rutil, kis og jernerts.

Amfibolit-granatamfiboliter opptrer også i Tingvollgruppen, og her også spesielt i fjellpartiet syd for Surnadalsfjorden.

En tilsvarende opptreden av amfiboliter i Røros- og Tingvollgruppen, og spesielt nær grensen mellom de to grupper, har jeg tidligere iakttatt i Molde—Tingvollsynklinalen. I overensstemmelse med min tolkning av disse amfiboliter, oppfatter jeg også Surnadalssynklinalens amfiboliter som metamorfe intrusiver.

Jeg vil her nevne den tanke at amfibolitene genetisk kan høre til Bymark—Størengruppens grønnskifre, opprinnelig trengt frem som en art subvulkaner i grenseområdet.

I Rørosgruppen ses to små kisforekomster, som begge er knyttet til amfibolit. Øst for Kvanne ligger en magnetkisforekomst med kobberkis. Forekomsten er nr. 56, Søiset skjerp, i Foslies oversikt

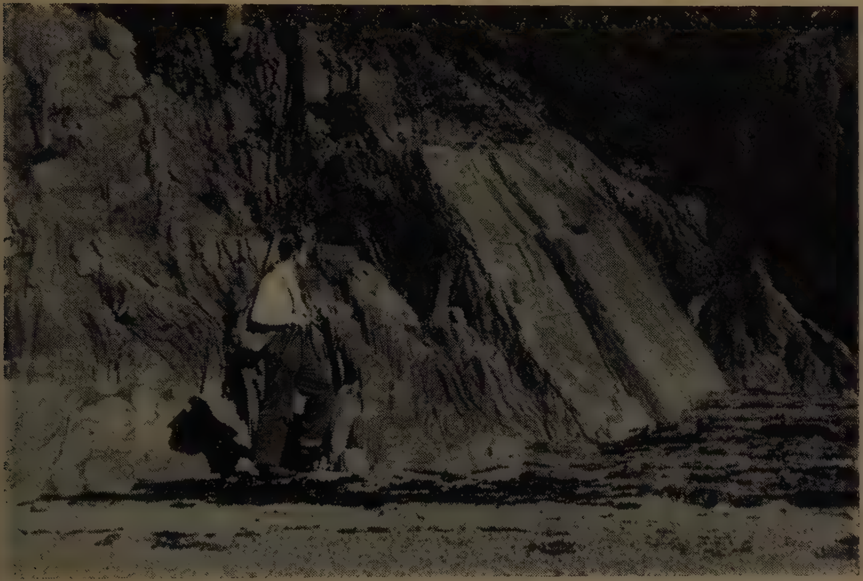

Fig. 5. Rørosgruppens basalkvartsskifersone, Årnes.
The basal quartz schist zone of the Røros Group, Årnes.

(Foslie 1925). I dette område ses ellers flere forekomster med kisimpregnert amfibolit. Den andre av de to kisforekomster ligger inn for bunnen av Surnadalsfjorden, på sydsiden. Det er en svovelkisforekomst, nr. 80, Vasenden grube, i Foslies oversikt.

Foruten amfibolit-granatamfiboliter ses tallrike ganger, slirer og linser av tronhjemit i glimmerskiferen. De oppfattes som dannet ved en mekanisk injeksjon av trondhjemitisk magma i glimmerskiferen. Dessuten har trondhjemitisk materiale metasomatisk fortrengt en del av glimmerskiferen. Karakteristisk er porfyroblaster av oligoklas.

Denne trondhjemitisering, sammen med de ovenfor beskrevne amfiboliter, har tildels gitt Rørosgruppen et gneisaktig preg. Tilsvarende forhold er iakttatt på Bolsøy ved Molde.

I Rørosgruppen er videre iakttatt tre små forekomster med serpentin-kleberstein. De ligger alle i Rørosgruppen over Bymark—Størengruppen, og her stratigrafisk i samme nivå, et stykke fra grensen mot Tingvollgruppen.

Et interessant trekk er at den stratigrafisk undre del av Røros-

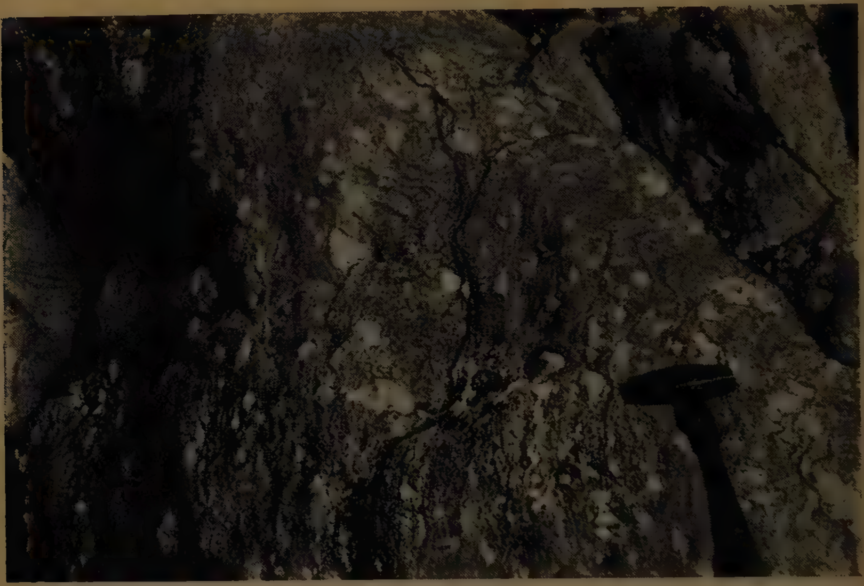

Fig. 6. Tingvollgruppens øverste øyegneissone, Årnes.
The upper-most augen-gneiss zone of the Tingvoll Group, Årnes.

gruppen over Bymark—Størengruppen er mere gneisaktig utviklet enn avdelingen ellers. Dette er et markert trekk i fjellpartiet syd for Surnadalsfjorden. Ved siden av glimmerskifer ses mere kvarts- og oligoklas-rike bergarter. Ved siden av den ovenfor nevnte trondhjemitisering må vi her primært ha hatt et mere sandig innslag i de ellers utpreget leirholdige mekaniske sedimenter avdelingen er dannet av.

I Molde—Tingvollsynklinalen har jeg utskilt en kvartsskifersone som basallag for Rørosgruppen. En tilsvarende sone er utviklet i Surnadalssynklinalen. En meget vakker lokalitet er strandområdet vestligst på halvøya mellom Hamnesfjord og Surnadalsfjord, se fig. 5. Tildels er sonen mere kvartsitisk utviklet enn ved Molde. Dette gjelder spesielt sonen i fjellpartiet syd for Surnadalsfjorden, altså nettopp innen det mere gneisaktige område som er omtalt i avsnittet ovenfor.

Rørosgruppen, som den her er skilt ut, viser avdelingens karakteristiske kjennetegn. C. W. Carstens har i sitt store arbeide om

Trondhjemsfeltet (1920, s. 57—66), foruten glimmerskifer og trondhjemit spesielt fremhevet amfibolit og peridotit som karakteristiske bergarter.

Tingvollgruppen og homogene gneiser.

Som sitt stratigrafisk øverste lag har Tingvollgruppen en meget karakteristisk øyegneissone, se fig. 6. Store og små mikroklinrike øyne ses om hverandre, og sonen minner enkelte steder atskillig om et konglomerat i utseende. Grunnmassens feltspat er oligoklas. Bare helt sporadisk og i ubetydelig mengde er granitisk materiale iakttatt å ha trengt igjennom Rørosgruppens basalkvartskifer — kvartsitsone og inn i skifrene.

Øyegneissonen er spesielt vakkert utviklet i fjellpartiet syd for Surnadalsfjorden, i Tingvollgruppen over Rørosgruppen. En tilsvarende øyegneissone ses også i Molde—Tingvollsynklinalen mot Rørosgruppen.

Et interessant spørsmål er hvor man skal sette Tingvollgruppens undre grense. Tingvollgruppen oppfattes som en eokambrisk avdeling, og det ville derfor være naturlig å sette grensen mot en eventuell prekambrisk avdeling eller et tektonisk brudd. Her kommer da spørsmålet inn hva de homogene gneiser opprinnelig er dannet av og av hvilken alder de er.

I Molde—Tingvollsynklinalen har H. Carstens og forfatteren ved kartleggingen utskilt en meget markert øyegneissone som Tingvollgruppens underste lag. Jeg har videre diskutert Tingvollgruppens undre grense, og omtalt en kvartsitsone inne i de homogene gneiser som et mulig basallag for Tingvollgruppen. Jeg har videre omtalt en kvartsitsone over den nevnte øyegneissone som et basallag for den øvre del av Tingvollgruppen.

Den nevnte øyegneissone i Molde—Tingvollsynklinalen fortsetter østover inn i Surnadalssynklinalen. Her danner den på sydsiden den nordligste del av Nesøya, og ses videre mellom Stangvik og Torslott hvor den kiler ut. På nordsiden av synklinalen fortsetter den østover som en meget smal sone. Sammensetningen av øyegneisen er granodioritisk til granitisk med røde, mikroklinrike øyne.

Kvartsitsonen over øyegneissonen kan også følges inn i Surnadalssynklinalen og den fortsetter på sydsiden videre øst—sydøstover, inntil den går ut i fjorden ved Kvanne.

Denne kvartsitsonen er så markert både i Molde—Tingvollsynklinalen og i Surnadalssynklinalen at jeg synes det er naturlig å fremheve den som basallag for en Øvre Tingvollgruppe.

Kvartsitsonen inne i de homogene gneiser i Molde—Tingvollsynklinalen ses østligst i synklinalen, nord for Meisingset, å gå over i opptil fire nærliggende parallelle kvartsitsoner. Dette antyder en bergartmessig endring, som er meget markert på Nesøya og i området Torslott—Kvanne. Istedetfor homogene gneiser ses her Tingvollgruppens bergarter. Et markert trekk er kvartsitsoner.

Etter dette finner jeg det mest naturlig å oppfatte kvartsitsonen inne i de homogene gneiser i Molde—Tingvollsynklinalen som basallag for en Undre Tingvollgruppe. Kvartsitsonen fortsetter inn i Surnadalssynklinalen over den sydlige del av Nesøya og går antakelig ikke i land i Torslott—Kvanne området. På Røkkumhalvøya står homogene gneiser.

Da de homogene gneiser under og over kvartsitsonen i Molde—Tingvollsynklinalen videre er helt like, er det et spørsmål om ikke også de underliggende homogene gneiser er eokambriske. Fortsatte undersøkelser vil muligens gi opplysninger om dette spørsmål.

Når det gjelder Tingvollgruppen over Rørosgruppen, altså i fjellpartiet syd for Surnadalsfjorden, er undersøkelsene ikke så inngående at en tilsvarende sammenlikning med Tingvollgruppen i Molde—Tingvollsynklinalen lar seg gjennomføre. En direkte sammenlikning vanskeliggjøres dessuten ved en forskjellig utvikling, et fenomen som ovenfor er omtalt iakttatt også i Rørosgruppen.

Av karakteristiske bergarter i Tingvollgruppen ses foruten øyegneiser og kvartsiter, glimmerrike, skifrige gneiser med kvartsdioritisk til granodioritisk sammensetning, og mere massive, glimmerfattige gneiser med kvartsdioritisk til granitisk sammensetning.

Tingvollgruppens biotit skiller seg tydelig fra Rørosgruppens. Biotitens pleokroisme er lys grønngul — mørk grønnbrun. Foruten kvarts, oligoklas, mikroklin og biotit ses epidot, klorit, muskovit, sericit, granat, erts, turmalin, apatit og titanit.

I overensstemmelse med min tolkning av Tingvollgruppen i Molde—Tingvollsynklinalen oppfatter jeg også Surnadalssynklinalens Tingvollgruppe som en eokambrisk avdeling dannet av jordarter i rekken sand-leire. Grensen mot Rørosgruppen markerer en primær overgang fra vekslende sedimenter til en mere ren leiravsetning. Under regionalmetamorfosen har Tingvollgruppen gjennomgått en granitisering med en kvartsdioritisk og en senere ren granitisk fase. Grensen mot Rørosgruppen er tilnærmet grensen for denne granitiske fase.

Tektonisk har jeg tolket feltet som en stor liggende fold, med ombøyning mot syd. Helt sydligst i det kartlagte felt, i området øst for Kvanne, har både Røros- og Tingvollgruppen et mere gneisaktig preg enn lengere nord. Rekognoserende undersøkelser på sydsiden av fjorden, øst for Røkkum, viser at gneiskarakteren her er enda mere fremtredende, selv om det dog er mulig å gjenkjenne enkelte soner fra Kvanneområdet.

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GRANULITT—MANGERITT— EKLOGITT

Granulite—Mangerite—Eclogite

AV

IVAN TH. ROSENQVIST

Abstract. The relation between the proposed granulite-, magnerite-, and eclogite facies is discussed.

As a result of investigations in Western Norway and Central Europe, combined with laboratory experiments, it is concluded that these three facies are representing more or less the same thermodynamic conditions. The string pertite type of the feldspar is characteristic.

Forord.

Den foreliggende avhandling ble fremlagt som foredrag ved det II. Nordiske Geologiske Vintermøte i Oslo, januar 1956. Avhandlingen er av preliminær natur og det har ikke vært mulig å gjennomgå det ganske omfattende materialet som foreligger og som kan belyse problemene grundigere. Når jeg allikevel har funnet det riktig å offentliggjøre arbeidet, først i form av foredrag og nå i trykk, så skyldes det at de problemer som behandles er av stor viktighet for forståelse av Norges høymetamorfe bergarter. Avhandlingen bør derfor ses på som et diskusjonsinnlegg og betraktes som en diskutert arbeidshypotese. Det feltarbeid som ligger til grunn for avhandlingen har i sin helhet vært støttet av Forskningsfondet av 1919 og av Oslo Kommunes Stipendium for Vitenskapelig og Industriell Forskning. Takket være dette siste stipendium var det mulig for meg å foreta en omfattende reise til de fleste mellom-europeiske granulittforekomster. Denne reise har vært av uvurderlig betydning for det syn jeg er kommet frem til. Jeg takker herved de to institusjoner, Forskningsfondet av 1919 og Oslo Kommune.

I en avhandling som utkom for et par år siden (11) behandlet jeg feltspatmineralenes og de metamorfe fasis. En av konklusjonene i dette arbeid var at granulittfasis og eklogittfasis er meget intimt forbundet. Begge fasis ble ansett å representere forholdsvis store dyp i jordskorpen og forholdsvis høye temperaturer. Noen skarpe grenser mellom granulittfasis og eklogittfasis anså jeg ikke mulig å trekke på krystallkjemisk grunnlag. Derimot var det noenlunde enkelt å definere en grense mellom den felles «eklogitt-granulittfasis» på den ene side, og gabrofasis eller hornfelsfasis og amfibolittfasis på den annen side.

Det viktigste krystallkjemiske kriterium ved granulitt-eklogittfasis er at biotitt ikke er stabil i denne fasis, men går over til granatmineraler (10). I de dypeste deler av fasisgruppen er disse granater av eklogitt-granattypen, dersom den kjemiske sammensetning av bergarten tillater slike granater å dannes. I den høyere del av fasisgruppen, svarende til lavere trykk, vil eklogittgranater vanligvis ikke dannes, men derimot almandin. En rekke av de norske eklogittforekomster inneholder således almandin og ikke den ekte eklogittgranat (1,7). For øvrig er det lite som skiller disse vestnorske eklogitter fra ekte eklogitter, og det kan neppe trekkes noe skarpt skille som skal gjøre det mulig å utskille de vestnorske «eklogitter» fra de ekte eklogitter.

Ved siden av de klassiske fasiskriterier slik som har vært skissert ovenfor, anså jeg det mulig å skille ut bergarter tilhørende amfibolitt- og eklogitt-granulittfasis på grunnlag av feltspatenes pertitt-type. Krystallkjemiske undersøkelser over diffusjonen av joner i kalifeltspat og plagioklas hadde vist at ved høy temperatur forelå det en utpreget diffusjonsanisotropi, slik at det geometriske sted for de differerende joner dannet et treaksig elipsoid med utpreget eksentrisitet. Under slike forhold må man forvente at den pertittype som utskilles, vil ha strengform eller spindelform. Det vil si at de typiske «jotunpertitter» er karakteristiske for utskillelsesformen ved høy temperatur og de ble ansett som et mulig fasiskriterium.

Ved undersøkelser utført i området Lesja—Tafjord og utover Sunnmøre, viste det seg at strengpertitter var forholdsvis vanlige også i gneisbergartene der, på tross av at disse gneisbergarter ikke på noen vanlig måte kunne sies å likne granulittene. Bergartenes alminnelige metamorfosegrad tilsvarte amfibolittfasis og ofte sogar epidotamfibolittfasis eller saussurittfasis.

Under et møte i Norsk Geologisk Forening for et par år siden gjorde dr. Tore Gjelsvik oppmerksom på at en prøve av gneis fra øya Runde, 30 km vest for Ålesund, hadde vist seg å inneholde rombisk pyroksen og granat. Vi er her inne i et mineralselskap som ligner meget sterkt på enkelte mellom-europeiske granulitter. Da dette funn interesserte meg meget, foretok jeg med støtte fra Forskningsfondet av 1919 en reise i de ytre kystdistrikter mellom Stad og Runde og samlet inn et forholdsvis omfattende materiale av gneiser og eklogitter fra dette område. Denne undersøkelse ga til resultat at man meget ofte finner finkornige gneiser med granat og altså også rombisk pyroksen. Feltspatene var i de aller fleste av disse bergarter av den tidligere beskrevne strengpertitt og antipertitt-type. Gneisene kunne ofte uten særlig brudd på vedtatt terminologi anses for å tilhøre Bergen—Jotunstammen. Gneisene hadde utpreget kaledonisk struktur og må anses for å være sterkt metamorfoserte i den kaledonske foldingsperiode.

I sitt sammenfattende arbeide (12) «Bemerkung zur Genese des Gesteins- und Mineralfasis der Granulitte» går K. H. Scheumann blant annet inn på betingelsene for granulittmetamorfosen. Han kommer til at granulittfasis og eklogittfasis er karakterisert ved høyt allsidig trykk og høy temperatur, dessuten ved stressfenomener. Derimot skriver han at «Ingen argumentasjon har fått ham til å anta at temperaturen har vært høyere enn den som er karakteristisk for hornfelsfasis». Som jeg skrev i min avhandling om feltspatmineralene og de metamorfe fasis, antok jeg nettopp at temperaturen ved eklogitt- og granulittfasis maksimalt var den samme som ved hornfelsfasis, og kriteriet for et skille mellom disse to fasis er vesentlig avhengig av trykket.

Den tørrhet som man stadig finner ved eklogitter og granulitter behøver ikke å skyldes noen særskilt høy temperatur, derimot er det tørrheten vi kan takke for at vi i det hele tatt har granittiske bergarter fra granulittfasis oppbevart. Hadde nemlig ikke bergartene vært så ekstremt tørre ville granittisk sammensatt utgangsmateriale overgått i et anatektisk magma.

Den belgiske professor Paul Michot som har holdt foredrag her i Norsk Geologisk Forening og som sommeren 1955 ledet ekskursjon i Egersundfeltet, har foreslått en fasis som han kaller mangerittfasis (9), svarende til den metamorfosegrad eller de krystalisasjonsbetingelser hvorunder Bergen—Jotunstammens vanlige bergarter krystalliserte. En slik betegnelse kan være brukbar på samme måte som man har betegnelsen gabbrofasis for de magmatiske bergarter og hornfelsfasis for de metamorfe bergarter som er krystallisert eller omdannet under forholdsvis høy temperatur og under et moderat trykk. Dersom ikke betegnelsen «mangerittfasis» skal anvendes på den rent magmatiske fasis, synes uttrykket mangerittfasis ikke å ha noen betingelse for å slå i gjennom, idet en ikke kan innse hvori trykk og temperaturforholdene under mangerittfasis atskiller seg fra granulittfasis og altså deler av den gamle eklogittfasis.

Det blir i dette korte foredrag ikke anledning til å gå inn på de forskjellige lokaliteter, men som et foreløpig resultat av de undersøkelser jeg har foretatt i området Rudihø, der dr. Tore Gjelsvik i sin tid gjorde sin hovedoppgave (3), og på Vestlandet fra Stadt til Runde samt i Bergensbuen og Egersundsfeltet, kommer jeg til en konklusjon som noenlunde kan sammenfattes på følgende måte:

Eklogitter, granulitter og Bergen—Jotunstammens magmatiske bergarter har alle krystallisert eller rekrystallisert under forhold med meget høyt trykk og høy temperatur, og de har derved fått mange fellestrekk. Da Bergen—Jotunbergartene herved er oppfattet som karakteristiske for et trykk-temperaturområde, er det vanskelig å opprettholde betegnelsen Bergen—Jotunstammens bergarter så lenge man ikke kan bevise at disse er cosanguine. Tvert i mot forekommer det meg som rimelig å anta at så og si en hver bergart vil få preg som er karakteristiske for Bergen—Jotunstammen, dersom de krystalliserer under tilsvarende fysikalske forhold. Jeg har derfor foreløpig kommet frem til en antagelse av at de såkalte Bergen—Jotunstammens bergarter representerer forskjellige ikke cosanguine bergarter. Noen av dem kan være prekambriske, noen av dem muligens eller sogar sannsynlig kaledonske. Dette syn må ikke oppfattes slik at jeg vil nekte for at det finnes magmatiske Bergen—Jotunbergarter. Tvert i mot synes en del lokaliteter å tyde på ekte magmatisk differensiasjon. Karakteristisk for de sure derivanter, er imidlertid at de må ha vært meget vannfattige, Dersom man har vannrikere utgangsmateriale, vil disse ikke kunne krystallisere under disse forhold og vil som magma trenge høyere opp i jordskorpen der trykket respektive temperaturen blir lavere. Jeg kan tenke meg at en god del av Oppdalitt—Trondhjemittstammens bergarter nettopp representerer slike magma som er presset opp i kaledonsk tid. De gabbroidbergarter dr.

Gjelsvik har behandlet under betegnelse «doleritter» (4) skulle kunne danne en slags mellomstilling mellom Bergen—Jotunstammen og Oppdalitt—Trondhjemittstammen.

Angående gneisene fra Stadt til Runde så er disse karakterisert ved at de alle inneholder glimmermineraler. Da slike mineraler ikke er stabile i granulittfasis, står man overfor en tydelig vanskelighet dersom man antar at dette gneiskompleks representerer opprinnelige kaledonske granulitter. Det er da på sin plass å gjøre oppmerksom på at særlig de moldanubiske, men også de sachsiske granitter meget ofte inneholder betydelige mengder glimmermineraler. Både Scheumann og Zoubeck har kunnet vise at disse glimmermineraler er av to forskjellige generasjoner. For det første har man den såkalte restbiotitt, dvs. biotitt som ikke har rukket å bli overført til granat. Dernest har man den sekundære biotitt og dette er den alminneligste. Man får altså de samme forhold som Kolderup antyder i den siterte avhandling.

Resultatet av disse overlegninger ble derfor at feltsmineralene som har karakteristiske streng- og spindelpertitter, er primære i forhold til glimmermineralene. Videre at den textur med avplattete kvartser og finkornige mineraler som man ofte finner, representerer det samme som man har i Mellom-Europas granulitt, men at diaftorese har vært mer virksom i Vest-Norge enn i Sentral-Europa.

Likeledes har den opprinnelige metamorfose vært mer intens i Vest-Norge enn ved de Sentral-Europeiske granulitter. I disse siste kan man ofte tydelig vise hva utgangsmaterialet har vært, nemlig både paramaterial og ortomaterial. I Vest-Norge er det knapt mulig med sikkerhet å vise utgangsmaterialets art på samme måte, selv om endel av de lyse «granulittbergarter» mulig kan sannsynliggjøres som metasparagmitter.

Granulitt, slik som den defineres av tyske, østerrikske og skandinaviske forskere, innebærer både tekstur-, assosiasjon- og fasiskriterier. I angelsaksisk og vel også i fransk litteratur benytter man «granulitt» vesentlig som et teksturbegrep. Etter denne definisjon ville det være mange av de leptittiske gneiser i nord-vest-området som er «granulitter». Etter min oppfatning er det ofte korrekt å betegne disse bergarter som meta-granulitter.

Nylig har professor Niels-Henr. Kolderup (6) publisert en artikkel over sammenhengen mellom skifre, gneiser og eklogitter i «nordvesttavlen.» Et av de store problemer som han her behandler er sammenhengen mellom eklogittenes tilsynelatende meget høye metamorfosegrad, og de omgivende skifre og bergarters vesentlige lavere metamorfosegrad. (Han oppfatter de forskjellige gneiser, migmatitter og granittiske bergarter som granittiseringsprodukter av opprinnelige skifere). Da disse gneiser må ha befunnet seg på samme dyp som de innleirete eklogitter, tenker han seg at gneisene en gang har vært i samme fasis som eklogitter, men senere er blitt overført til nåværende mineralfasis ved en ny metamorfose eller granittisering hvorved de siste har foregått relativt kaldt. Dette kan bringes bra i overensstemmelse med den observasjon at de fleste eklogitter har randsoner av eklogittamfibolitter eller amfibolitt, og at det dessuten finnes eklogittliknende mindre klumper syd for Sulen, som består av amfibolitt og granatamfibolitt. Dette tar Kolderup som et tegn på lavtemperaturmetamorfose, eventuelt med følgende granittisering som har gått til angrep på opprinnelige eklogitter.

Denne Kolderups oppfatning er meget interessant og dekker for en stor del en oppfatning jeg også har kommet frem til. Da vi her i Norge er dårlig utstyrt med ekte granulittiske bergarter, foretok jeg sommeren 1955 en reise til alle de klassiske granulittlokaliteter i Mellom-Europa. (I Sachsen, Böhmen, Mähren og Nieder Donau i Østerrike (5, 8, 10, 12, 13)). Jeg var så heldig å ha kontakt med de beste kjennere av disse bergarter, slike som professor Schüller i Berlin, dr. Zebera i Prag. Dr. Zebera har samarbeidet med Zoubeck i hans omfattende granulittarbeider. Videre har jeg vært sammen med professor Köhler i Wien. Felles for alle disse geologer er at de har kommet frem til den oppfatning at granulittene var ekte metamorfe bergarter, og *ingen av dem* har sett ekte granulitter som ikke har pertitter av strengtypen. Jeg har selv gått gjennom ca. 50 slip av granittiske og gabbrodiorittiske granulitter og funnet det samme.

Både i det sachsiske granulittmassiv og moldaubikum i Böhmen og Mähren finner man små eklogittpartier. Noen av disse har vært beskrevet av Hentschel (ved Frankenberg i Sächsische Zwischengebirge). Liknende forhold i Böhmen blir for tiden bearbeidet, ved den tsjekkiske geologiske undersøkelse.

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NOTISER

Sur une Palygorskite d'Åna-Sira (Norvège du Sud).

PAR

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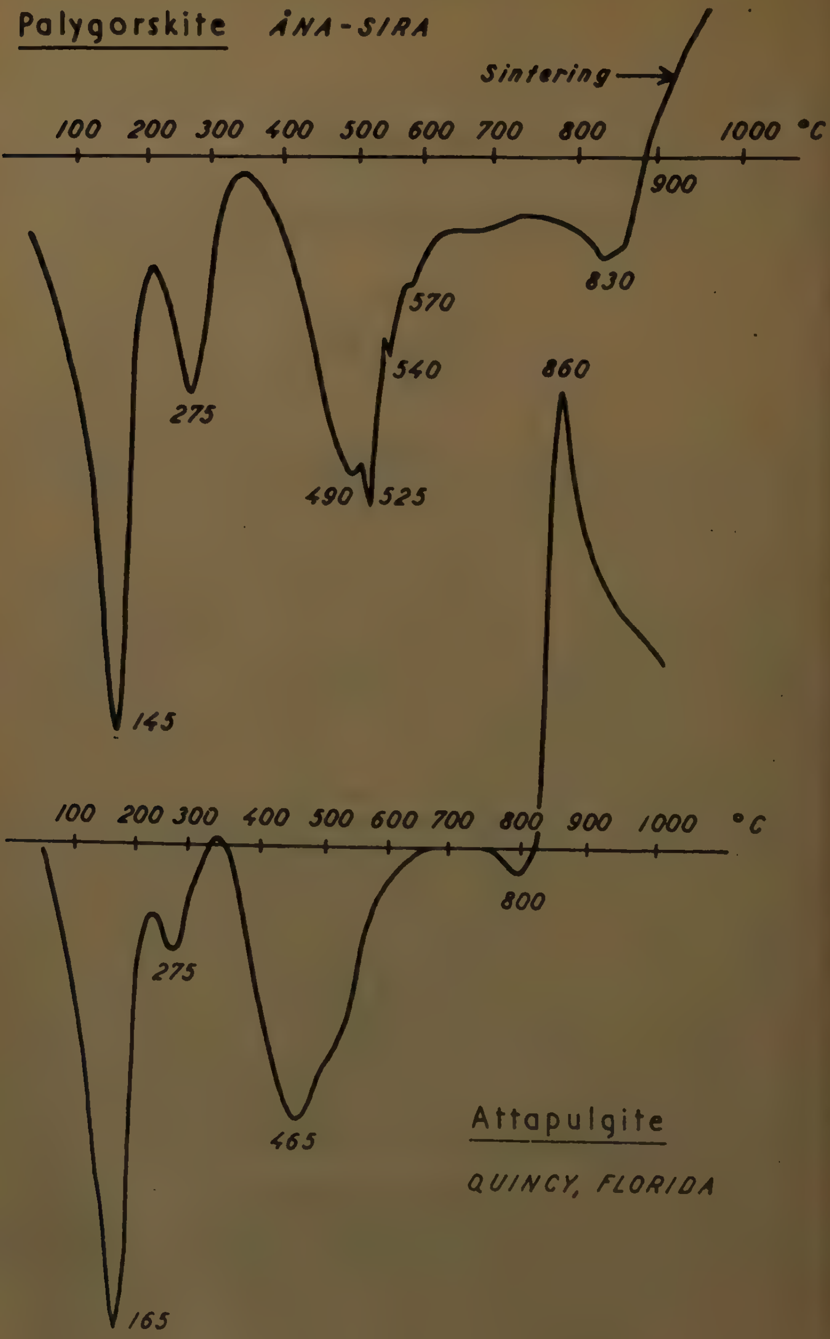
Abstract: Palygorskite occurs as sheets of mountain leather in some joints of the Åna-Sira anorthosite. The mineral has an hydrothermal mode of origin. Optical, chemical and DTA data are given.

Les joints qui traversent le massif anorthositique d'Åna-Sira sont en relation les uns, avec l'intrusion de dykes de mangéro-norite probablement précambriens, les autres, avec des dislocations régionales plus récentes du socle. Les premiers ont draîné les solutions résiduelles des mangéro-norites et sont caractérisés par un remplissage quartzo-feldspathique ilménitifère, souvent pégmatitique. — Ils sont recoupés et legérèment rejetés par les seconds, à partir desquels l'anorthosite et les dykes anciens sont saussuritisés, et ce avant tout dans des zones kakiritisées (vallée d'Åna-Sira).

Le remplissage des diaclases du second type est formé normalement par la paragenèse préhnite-épidote-quartz-carbonates. A la route menant d'Åna-Sira à Flekkefjord (plus précisément entre la bifurcation vers le Berefjord et la montée de Haaskog) j'ai observé à côté de joints pareils, d'autres fissures, qui rejetaient elles-aussi des veinules de pégmatite ilménitifère, mais dont le remplissage particulier était formé de plaques de carton de montagne (palygorskite).

Il n'est pas évident sur le terrain pourquoi il a pris naissance ici de la préhnite, là de la palygorskite. Dans les deux cas, la roche encaissante est une anorthosite grossièrement grenue, à bandes hololeucocrates et leuconoritiques. Il ne peut toutefois y avoir de doute sur le fait que la palygorskite s'est formée à la suite d'une attaque de l'andésine et de l'hypersthène de l'anorthosite par des solutions aqueuses d'origine profonde.

Le carton de montagne forme des feuilles étendues, de un à plusieurs mm d'épaisseur. Sa surface est lisse ou présente parfois des stries de glissement. Ce carton est constitué par un matériau blanc opaque, léger, assez flexible, qui ne se déchire que difficilement. C'est un feutre


Palygorskite ÅNA-SIRA
Sintering
100
200
300
400
500
600
700
800
1000 °C
900
830
570
540
275
490
525
145
860
100
200
300
400
500
600
700
800
900
1000
°C
800
275
465
165
Attapulgite
QUINCY, FLORIDA

de fibres enchevêtrées, couchées de préférence dans le plan du joint. Le minéral fibreux n'est accompagné par aucune impureté, comme le montre l'étude microscopique, ainsi qu'un diagramme Debye-Scherrer.

Ce dernier est caractéristique d'une palygorskite.

Le minéral d'Åna-Sira a les propriétés optiques suivantes:

Ng = 1,532 +/— 0,001
Np = 1,524 +/— 0,001
Ng—Np = 0,008 +/— 0,002
(—) 2V = environ 60° (difficile à mesurer avec précision par suite de superpositions de fibres)
Ng = parallèle à l'allongement.

Chauffé au Bunsen, la palygorskite se contracte un peu en prenant une teinte grisâtre, puis fond en un émail blanc bulleux.

Son analyse chimique a conduit aux résultats suivants:

	% poids	prop. cations	
SiO_2	56,30	938	
TiO_2	néant	—	
Al_2O_3	12,58	246	
Fe_2O_3	0,43	5	(Fe total comme Fe_2O_3)
MnO	trace	—	
MgO	9,66	240	
CaO	0,19	3	
$H_2O +$	12,19	1354	
$H_2O -$	8,98	998	
	100,33		analyste P. Antun.

La formule générale des palygorskites n'est pas encore définitivement établie. Mon analyse pourrait très bien se traduire par

$$MgAlSi_4O_{10}(OH) \, . \, 4.4H_2O$$

Le diagramme obtenu par l'analyse thermique différentielle (Fig. 1) montre en effet qu'un groupe (OH) est lié au réseau. L'attapulgite de Quincy (Florida) présente un comportement tout à fait comparable, ce qui prouve une fois de plus que les deux termes, palygorskite et attapulgite, s'adressent à la même substance et que le second synonyme est superflu.

Remerciements. Je remercie sincèrement Mr. le prof. Tom. F. W. Barth, de l'Université d'Oslo, pour son aide et ses conseils, Mr. Sæbø, étudiant au Geologisk Museum Oslo, pour la prise d'un diagramme Debye-Scherrer et Mr. le statsgeolog R. Selmer-Olsen, qui a bien voulu effectuer dans son laboratoire les deux analyses thermiques différentielles.

Addendum by T. F. W. Barth.

Mountain leather has been observed at various localities in Norway but never further investigated. Antun's description of the Åna-Sira material prompted us to investigate with x-rays some additional specimens of mountain leather that were available to us. (The diagrams were taken by Mr. P. Sæbø). Two of the specimens gave x-ray powder patterns identical to that from Åna—Sira, and are thus additional examples of Norwegian palygorskites.

Both specimens were collected in 1937 when the railroad was under construction west of Kristiansand. In the upland («hei») between Greipstad and Øyslebø the railroad follows a breccia zone. On joints and sheared surfaces large sheets of white mountain leather composed of *palygorskite* and *calcite* were found at Fossestøl; more earthy varieties of the same substances filling cracks were collected at Krossen. These localities are at the railroad track 1 and 2 km respectively, east of the lake Høyevann.

Other minerals occurring in this system of breccia zones are *hematite* (compact, platy, red hematite) and, on the track just south of Høye Station, *pyrolusite* in composite groupings of needle-like lustrous crystals (polianite). Manganese oxides have been known to occur in fissures in the gneisses around Kristiansand and Mandal (S. Foslie, N. G. U. no. 126, 1925) but large, well-defined crystals (polianite) have not been described before.

A pulverizer for micas and micaceous minerals.

by

HENRICH NEUMANN

The process of grinding micas in an agate mortar to a powder sufficiently fine for x-ray work is both tedious and awkward. Even after a thorough grinding the grains still have a sufficient size to give spotted films because of single crystal reflections. This effect can be avoided by prolonged grinding, but then the lines will often be blurred and too poorly defined for accurate measurement, probably as a result of distortions of the crystal structure because of the weak bonding between individual layers of the mica lattice. Crushing in the several different types of commercial mills gives equally unsatisfactory results.

A mica pulverizer built in the Mineralogical Museum of Oslo University works so well that it would seem worth while publishing details of its construction.

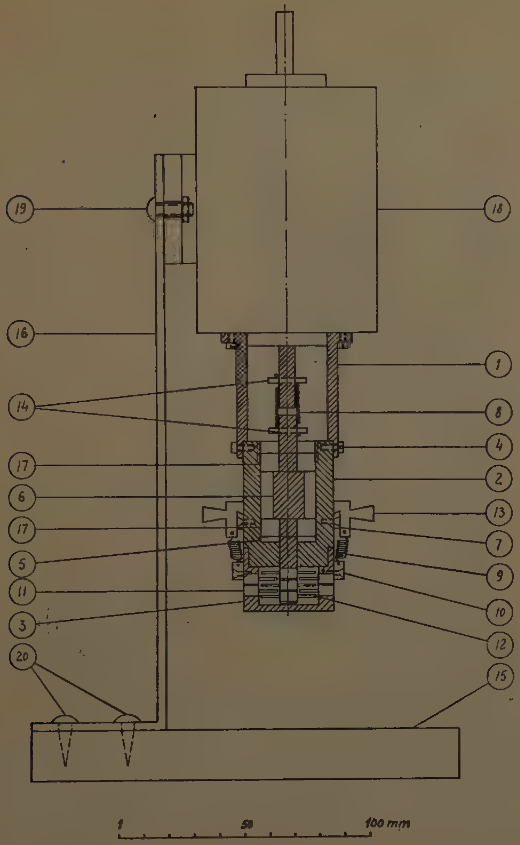


Fig. 1. Drawing of the mica pulverizer giving details of the construction. 1. Connecting ring. 2. Ballbearing holder. 3. Container. 4. Screwed disc. 5. Disc. 6. Axle. 7. Ring. 8. Spring. 9. Spring. 10. Spring-fastener. 11. Fixed knives. 12. Rotating knives. 13. Clamp. 14. Pin. 15. Base. 16. Stand. 17. Ballbearing. 18. Motor, 1/10 Hp., 9000 rpm. 19. Nut and bolt. 20. Wood-screws.

The principle is very simple: mica particles floating in the air are hit by sharp knife edges which split them without causing any lattice distortions. In practice this is effected by having two sets of knives in a small container, one set fixed and the other revolving at a speed of 9000 r.p.m. The edges of the two sets of knives face each other, and the knives are sufficiently far apart to give no scissor effect. The revolving knives are «feathered» so as to cause the mica grains to whirl about within the container when the pulverizer is running. The details of the construction are given in Fig. 1.

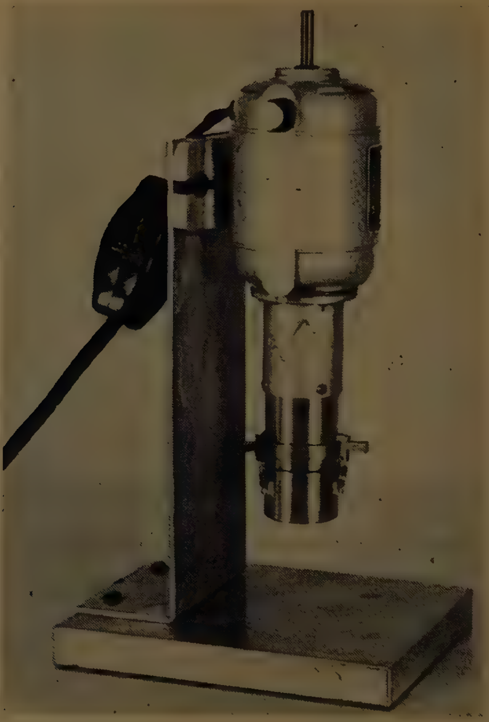


Fig. 2. The mica pulverizer.

The pulverizer may be built on a large or small scale according to requirements. The one drawn in Fig. 1 works well with samples from 0.01 gms to 2 gms, which are reduced to powders of x-ray size in 10 minutes. The powder is fine enough to keep the preferred orientation effect to a minimum. If a very high degree of accuracy in the intensity measurements is required, this effect can be eliminated in the conventional way by making the spindle of a not too finely reground, wetted and dried mixture of the mica powder with an amorphous, low-resorbing substance such as organic coal and a little gum tragacanth.

The principle of the instrument was outlined by the author to instrumentmaker Thorolf Nordby, who with his usual skill designed and built it.

Rapid crystal growth in a glass at room temperature.

BY

OLAV H. J. CHRISTIE

During the microscopical examination of the crystals mentioned in the following note, I have been able to follow growth of nepheline crystals at room temperature during 3 days. The growth of the crystals is shown in Figs. 1 and 2.

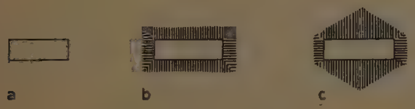


Fig. 1.

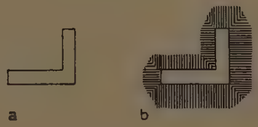


Fig. 2.

Fig. 1. a) initial stage, formed at 1015° C, b) crystal after one day at room temperature, c) end stage, obtained in 3 days.

Fig. 2. a) initial stage, formed at 1015° C, b) crystal after heating up to 700° C for 15 minutes.

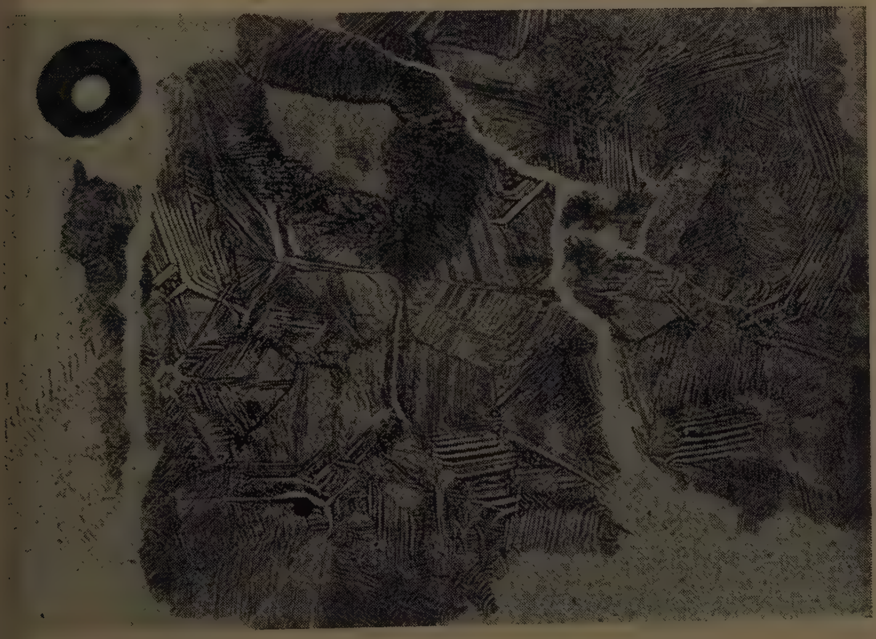


Fig. 3. Nepheline from a corroded refractory stone.

It has not been possible to analyze the crystals as they are small and almost black, due to Fe_2O_3 absorbed from the surrounding glass. (Table 1 in the following note). In all probability we are dealing with nepheline. The fibrous form of nepheline is shown in Fig. 3, well known from samples of corroded glass furnace bricks.

It has not been possible to repeat the rapid growth at room temperature. I have made more than 50 attempts, but all the experiments have been unsuccessful. I have been able, however, to reproduce the initial stage in one case, and the end form in numerous cases. By heating the initial stage to ca. 700° C for 15 minutes, the fibrous form was developed. Normally the growth of the crystals in the studied glass is exeedingly slow at this temperature.

Possible sub solidus phase borders in the corundum field of the system SiO_2—Al_2O_3—Na_2O

BY

OLAV H. J. CHRISTIE

Crystals formed in a glass taken from the surface of an industrial glass tank furnace refractory brick of the melting zone have been studied. The results indicate the presence of two, possibly three, sub solidus phase borders in the corundum field of the SiO_2-Al_2O_3-Na_2O diagram.

The top of the furnace was made of «Silicastones», containing ca. 98 $^0/_0$ SiO_2. The alkaline vapors from the glass batch condence on the ceiling and cause the formation of a SiO_2-Na_2O glass. The viscosity of this glass decreases as the Na_2O content increases, and finally it will run down to the walls of the furnace. The wall bricks, having a composition according to Table 1a, will be corroded by the SiO_2-Na_2O glass and add Al_2O_3 to it. The studied glass, thus formed, had a composition according to Table 1b.

	a	b
SiO_2	33 %	58,3 %
Al_2O_3	67 %	27,0 %
Fe_2O_3...........		0,3 %
CaO		1,6 %
Na_2O		12,9 %
	100	100,1

Table 1, chemical composition, a) of the unattacked refractory stone, b) of the studied glass.

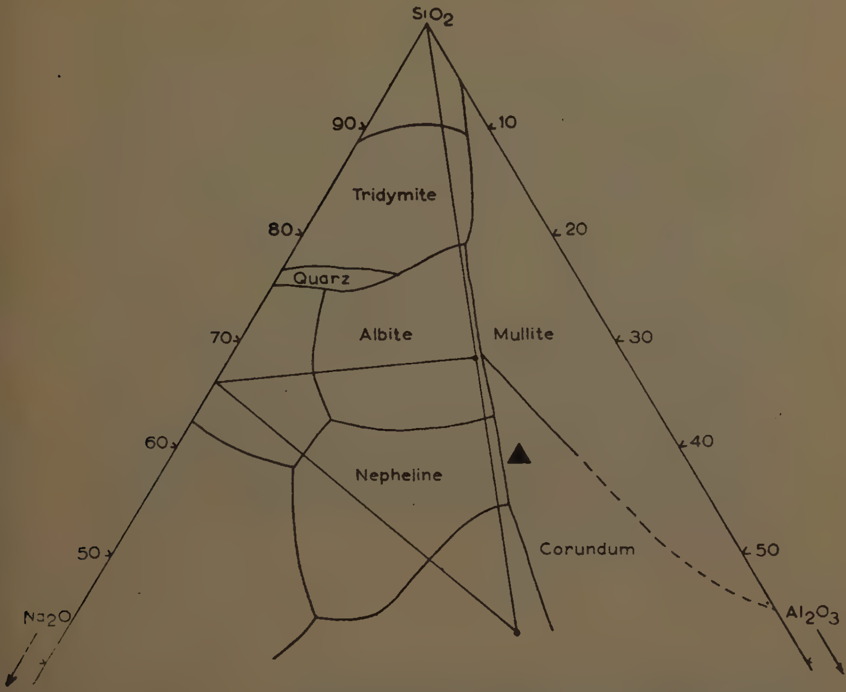


Fig. 1. Part of the phase diagram SiO_2-Al_2O_3-Na_2O. The studied glass marked by a triangle.

The chemical composition of the glass, marked by a triangle, is projected into the pure SiO_2-Al_2O_3-Na_2O phase diagram in Fig. 1.

The studied glass from the glass covered refractory brick was remelted and ground until uniform index of refraction was obtained.

The glass was heated at different temperatures in a platinum furnace. The temperature readings were made with a Pt-90Pt10Rh thermocouple calibrated against a standard thermocouple from the U. S. National Bureau of Standards.

The habit of the crystals formed during the heat treatment was studied under the microscope. The crystals were analyzed by x-ray analysis.

Microscopical Examination.

One sample was kept at 1270° C for 15 minutes. The index of refraction of the very small crystals formed during this heat treatment was much higher than the index of refraction of the glass. Because of lack of material it was not possible to analyze these crystals by means of x-ray. They are supposed to be corundum.

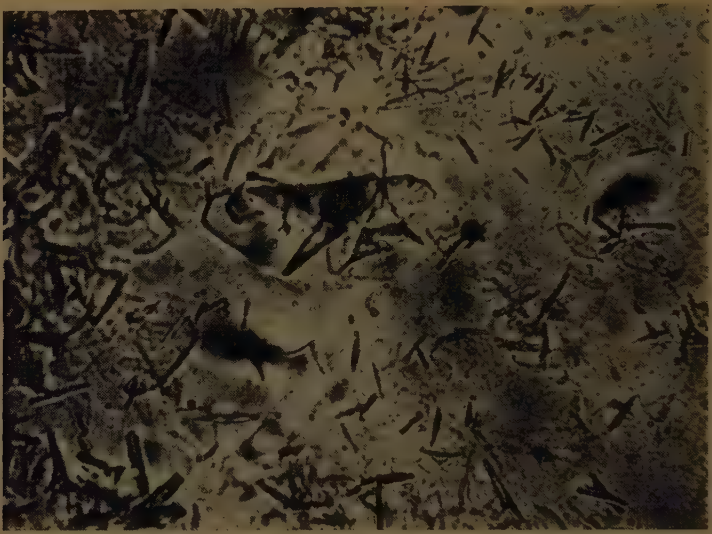


Fig. 2. Normal habit of albite obtained by devitrification above 1020° C.

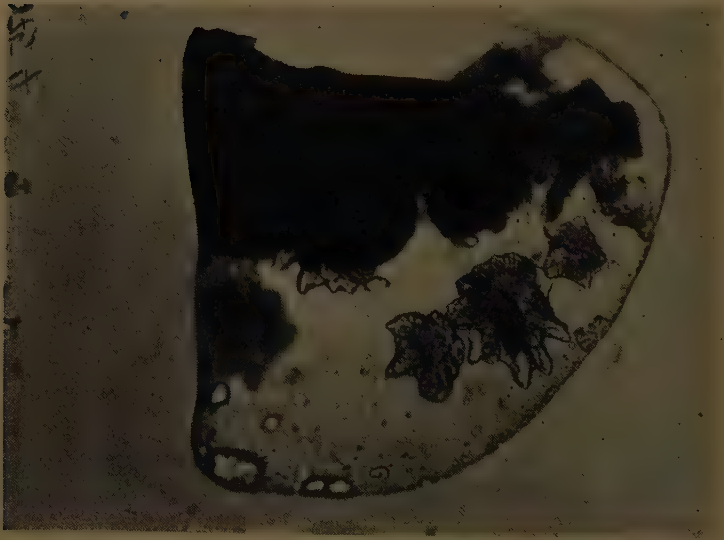


Fig. 3. Normal habit of nepheline obtained by devitrification below 1015° C.

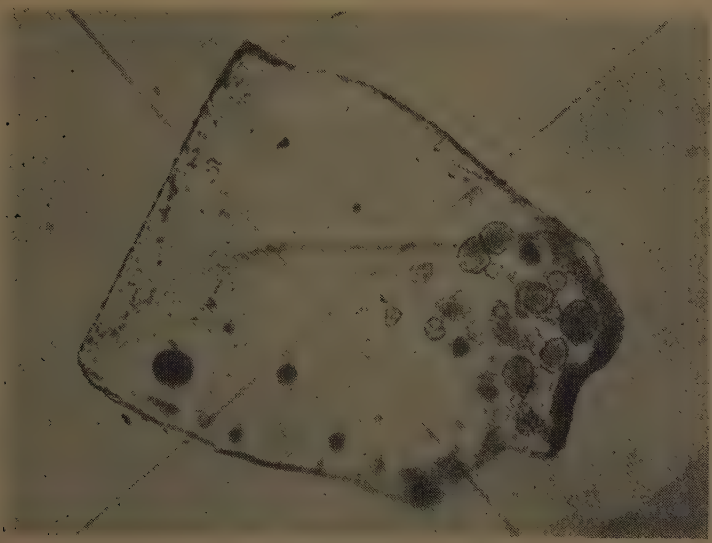


Fig. 4. Crystals formed at 860° C.

There was a change of the habit of the crystals at 1015° C—1020° C. Above 1020° C crystals as shown in Fig. 2 occured, below 1015° C crystals as shown in Fig. 3 occured. There was another distinct change of the habit of the crystals at ca. 800° C. These crystals are shown in Fig. 4. The growth of the crystals at this temperature, however, was too slow to give sufficient material for x-ray analysis even after 5 weeks.

X-ray Analysis.

The results from the powder patterns of the studied glass heated at different temperatures are shown in Table 2.

Degree Centigrade	Crystals formed according to powder pattern
1150	Albite
1047	Albite
1035	Albite
1020	Albite
1015	Nepheline
1005	Nepheline
995	Nepheline

Degree Centigrade	Crystals formed according to powder pattern
980	Nepheline
960	Nepheline
860	No Lines

Table 2, Devitrification products at different temperatures.

The lines of albite formed in the studied glass are rather indistinct, but the observed 10 strongest lines had the same spacing as the 10 strongest lines in the pattern of albite from Schmirn, Tyrol, our record number 2283. The fact that albite was found at 1150° is due to an admixture of the anorthite molecule.

The lines of nepheline formed in the studied glass are sharp and correspond to those of nepheline from Ariccia, Alabama Mountains, our record number 2260.

One sample was kept at 980° C to show if nepheline is metastable in the studied glass at this temperature. The powder pattern indicates that the nepheline was unchanged after 3 weeks. Another sample was kept at 1047° C, and the powder pattern indicates that the albite was unchanged after 1 week.

Conclusion.

This investigation indicates the presence of two, possibly three, sub solidus phase borders in the corundum field of the phase diagram SiO_2-Al_2O_3-Na_2O. The temperature of the phase border corundum-albite in the studied glass in unknown, the phase border albite-nepheline is, in this glass, situated at 1020° C—1015° C. The microscopical examination showed another change of the crystal habit at 880° C — 860° C. It is not known, whether this change is merely a change of the habit of nepheline, or if it indicates the presence of a crystal which is not nepheline.

ACKNOWLEDGEMENTS

Miss E. Christensen, Geological Survey of Norway, made the chemical analysis of the glass, the x-ray films were taken by Mr. Sellevoll, Mr. Sæbø and Mr. Sverdrup, and dr. H. Neumann kindly assisted in the interpretations of the x-ray patterns of the crystals.

Professor T. F. W. Barth placed at my disposals the laboratory facilities of Mineralogisk Geologisk Museum. To these persons I wish to express my sincere thanks.

Oslo November 1955.
Mineralogisk Geologisk Museum.

Appendix.

It is in this connection of interest to mention, that dr. J. H. Welch, in a lecture delivered at the 3rd. International Congress of The Activity of Solids in Madrid April 1956, reported the formation of corundum at sub solidus temperatures in a glass of the composition of of anortite.

NORSK GEOLOGISK FORENING

Møte 362, torsdag 10. november 1955.

Til stede 38 medlemmer, 16 gjester.

Følgende innvalg ble godkjent:

391 Per-Fredrik Trøften, bergingeniør. c/o Geofysisk Malmleting, Trondheim, foreslått av K. Heier og S. Skjeseth.
392 Ottar Jøsang, stud. mag. scient. Geologisk institutt, Universitetet, Blindern.
393 Borghild Nilssen, stud. real. fru, Geologisk Museum, Sarsgt. 1. Oslo 47.
394 Thor Lorck Sverdrup, cand. mag. Geologisk institutt, Universitetet, Blindern.
395 Per Chr. Sæbø, cand mag. Geologisk Museum, Sarsgt. 1. Oslo 47, foreslått av H. Neumann og T. Barth.
396 Håkon Lien, cand. mag. Viggo Hansteens gt. 4, Lillestrøm, foreslått av J. A. Dons og T. Strand.
397 Kari Egede Larssen, geol. ass. Norges geologiske undersøkelse, Josefinesgt. 34. Oslo, foreslått av P. Holmsen og Chr. Oftedahl.
398 Wm. Scott Mackenzie, dr. Geophysical Laboratory, 2801 Upton Street, Washington 8. D. C., foreslått av Chr. Oftedahl og L. Størmer.

Formannen foreslo at Norsk Geologisk Tidsskrift bør inneholde korte abstracts av geologiske avhandlinger som blir trykt i andre norske tidsskrifter.

Foredrag: «*Om Eokambrium og grensen mot Kambrium*».
Professor dr. *O. Holtedahl:* «Historisk oversikt».
Statsgeolog *S. Skjeseth:* «Mjøstraktene».
— *P. Holmsen:* «Østerdalene».
Direktør *S. Føyn:* «Finnmark».

I ordskiftet etter foredragene deltok:

L. Størmer, T. Strand, Chr. Oftedahl, H. Rosendahl, C. Bugge og foredragsholderne.

Møte 363, (julemøte) torsdag 15. desember 1955.

Til stede 31 medlemmer, 19 gjester.

Foredrag av statsgeolog *Thor Siggerud:*
«Geologiens rolle i arbeidet med atomenergien»
I ordskiftet etter foredraget deltok: I. Rosenqvist, P. Holmsen, T. Barth, H. Rosendahl og foredragsholderen.

Generalforsamling torsdag 16. februar 1956.

i Drammensveien 78, Oslo.
Til stede 20 medlemmer, 2 gjester.

Årsmelding for 1955.

Siden siste generalforsamling er følgende medlemmer avgått ved døden:

Direktør S. Meyer Smith, bergmester Andreas Holmsen.

1 medlem er utmeldt av foreningen. I samme tidsrom er innvalgt 13 nye medlemmer. Foreningen har nå 231 medlemmer, derav
2 korresponderende,
108 livsvarige og
121 årsbetalende medlemmer.

Det er avholdt 6 ordinære møter med samlet fremmøte av 232 personer.

Av Norsk Geologisk Tidsskrift er utkommet Bd. 34 h. 2—4 og Bd. 35. Meldingen ble vedtatt.

Årsmelding for Bergens geologiske klubb ble opplest. Melding fra Trondheims geologiske klubb forelå ikke.

Regnskapet for 1955 ble fremlagt og godkjent.

Utdrag av regnskap for det ordinære budsjett for 1955.

Inntekt:

Beholdning, overført fra 1954:				
I kasse	kr.	880,71		
I bank	-	8 198,18	kr.	9 078,89
Innbetalt medlemskontingent			-	1 878,00
Tilskudd fra staten			-	1 200,00
Tilskudd fra Norges Almenvitenskapelige Forskningsråd			-	12 000,00
Abonn. og salg av tidsskriftet			-	3 024,53
Renter av bankinnskudd			-	106,00
Renter fra livsvarige medlemmers fond			-	586,16
Renter fra Berg- og steinindustriens gavefond			-	498,79
			kr.	28 369,37

Utgift:

Tidsskriftet:		
Trykking bind 34 h. 2—4		kr. 7 509,00
— 35 h. 1—4 (avdrag)		- 8 828,00
Klisjeer bind 34 h. 2—4		- 1 821,00
— 35 h. 1—4		- 3 172,00
Korrektur, tegnearbeid og ekspedisjon av tidsskriftet		- 1 606,45
Arbeidshjelp, porto og skrivesaker		- 693,40
Møter og ekskursjoner		- 523,37
Representasjon, anskaffelser og Reuschmedaljen		- 63,16
Beholdning overført til 1956:		
I kasse	kr. 1 105,50	
I bank	- 3 047,49	- 4 152,99
		kr. 28 369,37

Livsvarige medlemmers fond.

		Inntekt	Utgift
1955 1/1. Fondets kapital:			
I statsobligasjoner	kr. 500,00		
I aksjebrev	- 4 600,00		
Bankinnskudd	- 11 260,00		
	kr. 16 360,00		
Innb. kont. i 1955	- 950,00		
Urørlig kapital pr. 31/12—55:	kr. 17 310,00		
Renter av verdipapirer		kr. 530,50	
— bankinnskudd		- 62,66	
Forvaltning av verdipapirer			kr. 7,00
Overført til ordinært budsjett			- 586,16
		kr. 593,16	kr. 593,16

Berg- og steinindustriens gavefond:

Fondets kapital	kr. 20 000,00		
Renter for 1955		kr. 498,79	
Overført til ordinære budsjett			kr. 498,79
		kr. 498,79	kr. 498,79

Regnskapet revidert av T. Strand og T. S. Winsnes: 13/1—56.

Reuschmedaljen for 1955 ble tildelt konservator G. Henningsmoen for hans arbeider: «Lower Ordovician ostracods from the Oslo Region, Norway» og «Upper Ordovician ostracods from the Oslo Region, Norway». N.G.T. bd. 33, s. 41—68 og s. 69—108.

Valg:

Formann: *Nils Spjeldnæs.*
Viseformann: *T. Strand.*
Sekretær: *S. Skjeseth.*
Redaktør: *N.-H. Kolderup.*

Styremedlemmer: *Chr. Oftedahl, Rosenlund,* og formennene i Bergens og Trondheims geologiske klubber.

Reuschmedaljekomité: *I. Oftedahl, J. Låg* og foreningens formann, *N. Spjeldnæs.*

Revisorer: *T. Gjelsvik* og *T. Winsnes* med *G. Henningsmoen* og *T. Siggerud* som varamenn.

A. Granli ble anmodet om å fortsette sin virksomhet som forretningsfører.

Møte 364, torsdag 16. februar 1956.

Til stede 23 medlemmer, 4 gjester.

Følgende innvalg ble godkjent:

399 Mr. Richard Cameron, p. t. Geologiska Institutet, Stockholms Högskola, Kungstensgatan 45, Stockholm Va, Sverige, foreslått av Ivar Hessland og Gunnar Henningsmoen.

400 Cand. mag. Harald Skålvoll, N.G.U. Josefinegt. 34, Oslo.

401 Stud. real. Ole K. Ihle, N.G.U. Josefinegt. 34, Oslo.

402 Tekn.ass. John Wilhelmsen, N.G.U. Josefinegt. 34, Oslo, foreslått av Chr. Oftedahl og S. Skjeseth.

403 Dr. Nils Edelman, Havari gruva, Viljakkala, Finnland, foreslått av J. A. Dons og H. Neumann.

404 Driftsleder, berging. Karl Ingvaldsen, Røros Kobberverk, Røros, foreslått av J. A. Dons og Chr. Oftedahl.

a) Minnetale over bergmester A. Holmsen ved dr. *Carl Bugge.*
b) Foredrag av prof. *Kirk H. Stone* (Madison, Wisc.): «The problems of Alaskan Ice-dammed Lakes».

Årsmelding for 1955 fra Bergens geologiske klubb.

Møte nr. 53, 16. mars.

Foredrag av dosent dr. *Anders Kvale:* «Dekkestrukturer mellom Bergensbuene og Voss, og litt om våre fjellkjedeproblemer.» 10 til stede.

Møte nr. 54, 20. april.

Foredrag av amanuensis *Ivar Hernes:* «Geologiske undersøkelser i Nordmøre og Romsdal.» 9 til stede.

Møte nr. 55, 17. desember. Julemøte.

Kåseri av amanuensis *Ivar Hernes:* «På kryss og tvers gjennom Alpene.» Med fargelysbilder. 28 til stede. Etter foredraget selskapelig samvær på Geologisk institutt.

Styret var i 1955: Formann, dosent Anders Kvale; viseformann, lektor A. Samuelsen; sekretær, amanuensis Ivar Hernes.

SECOND NORDIC GEOLOGIC WINTER MEETING

II Nordiske Geologiske Vintermøte.
Oslo, January 5.—7., 1956.

For many years Nordic geologists used to arrange summer meetings and excursions. Proceedings are printed in Norsk Geologisk Tidsskrift, vol. 27, 1949; Meddelelser fra Dansk Geologisk Forening, vol. 12, 1951, and Geologi, vol. 6, No. 1, Finland 1954.

A general wish to arrange meetings with lectures, discussions and symposia was fulfilled by the First Nordic Geologic Winter Meeting held i Gothenburg January 7.—9. 1954, president professor Gunnar Beskow, secreatary dr. P. Ljunggren. There were 108 participants (Denmark 12, Finland 7, Iceland 1, Norway 24, Sweden 62, and one each from Belgium and the U.S.A.).

A standing *Committee on Winter Meetings* was established: Noe-Nygaard (Denmark), Rankama (Finland), Tómas Tryggvason (Iceland), Barth (Norway), Wickman (Sweden). The proceedings are printed in Geol. För. Förh. 1954, vol. 76, pp. 330—336.

Plans were made to arrange for the Second Winter Meeting, which was held in Oslo, January 5.—7., 1956, president T.F.W. Barth, secretary J. A. Dons. There were 139 participants from the following countries: Denmark 11, Finland 7, Norway 76, and Sweden 43.

By special invitation professors F. Machatschki (University of Vienna) and A. Pabst (Berkeley, California) attended the meeting. Both had been studying with professor V. M. Goldschmidt in Oslo 25 years ago.

During the sessions 42 papers were read and discussed. In addition there were arranged two round table conferences:

1) «Eocambrian, Extent, and Subdivision», opened by professor O. Holtedahl and dr. B. Asklund.

2) «Water in Soils», opened by professor G. Beskow and dr. I. Th. Rosenqvist.

Professor Barth retired from the standing Committee on Winter Meetings, in this place professor L. Størmer was elected. It was agreed to elect a *Commission on an Academic Text-Book of the Geology of the Nordic Lands.* — President, Sven Gavelin (Sweden), Th. Sorgenfrei

(Denmark), A. Simonen (Finland), J. A. Dons (Norway), (member from Iceland not yet decided).

The Royal Department of Church and Education arranged a dinner at Frognersæteren Restaurant. Host was Minister Birger Bergersen.

The Third Nordic Geologic Winter Meeting will be held at Helsinki (Helsingfors), Finland 1958.

The meeting was opened and the Retiring President, professor Gunnar Beskow, delivered an address, an abbreviated version of which is here printed:

Beskows tale.

Geologerna är en liten yrkesgrupp. De nordiska länderna är en liten grupp små stater. Detta är grunden för ett möte som detta: alla känner alla, ja vi möts som i en nära vänkrets.

Då kan ju den utomstående fråga sig: Är en sådan här konferens behövlig? (Så tycks i beklagligt många fall de reseanslagsbeviljande myndigheterna ha tänkt). — I den lilla nordiska geologkretsen där alla är nära bekanta, där hålles väl också så nära facklig kontakt, att alla vet vad alla sysslar med, känner deras sista rön och resultat.

Så är det ej. Långa distanser skiljer de geologiska institutionsorterna. Ofta, alltför ofta, är geologen en flyttfågel mellan två ensamheter: arbetsfältet och arbetsrummet.

En konferens som denna har en betydande uppgift att fylla.

Geologien kännetecknas av sin vidd och mångsidighet . . . .Frågar någon geologen: vad är ditt yrke? kan han svara: *Jag utforskar naturen.*

Det är ju yrkets dragkraft och charm: från empiriskt fältstudium ute i geografien till laboratoriebehandling med den fysikaliska grundforskningens senaste metodik. Inte bara experimentell naturforskning, men *naturhistoria:* klarlägga ett skeende som är rytmiskt-periodiskt men dock unikt, som akterna i ett drama..... Geologen är Moder Geas levnadstecknare — och har som sådan yrkesanknytning till biologi och arkeologi och etnografi.

Men uppgiften är ju också att praktiskt nyttiggöra vår moder. Geologiens äldsta tekniska tillämpning, malmletningen — var finner man koppar? var finner man guld? var finner man uran? — har icke blivit ensam. År 1956 visar ett ganska omfångsrikt kortregister under samlingsrubriken: «tekniskt tillämpad geologi».

Vart vill talaren komma?

Han vill bara hårdast möjligt framhålla konflikten mellan det geologiska arbetsfältets vidd och tvånget till allt trängre specialisering. Fältets väldiga yta — och från varje punkt på ytan specialforskning och metodik driven till sådant djup, att kunskapsvolymen blir överväldigande omöjlig för en person att behärska.

Omöjlig att behärska. Ja. Men vad man vill önska oss alla specialister inom den geologiska vetenskapens vida gränser, det är: *någorlunda orientering* inom hela fältet .... Det är där en konferens som denna har sin väldiga uppgift.

En särskild glädje för nordiska geologer är det att få mötas här i Oslo. För oss som bor på den fennoskandiska urbergsplattan har Norden tre geologiska äventyrsländer. Danmark, som geologiskt är en del av Europa — det fina svanhuvudet på kontinentens geologiska bål. Vulkanismens och gejsrarnas sagoö, Island. Och Norge —.

När man österifrån via mellersta Norrlands peneplanerade gnejsgranit-tema nalkas fjällkedjan, så känner man hisnande: nu börjar det verkliga dramat! Ett drama som stegras ju längre man kommer västerut mot Kölen och bortom — det drama vars stora skapelse heter Norge.

Nu ligger visserligen Osloområdet marginalt till själva fjällkedjedramatiken — men är likväl därav fyllt, likt ett förspel eller en prolog. Oslo. Mötespunkt mellan det resistenta urbergsblocket och den högfjällsdanande, kustlinjeskapande orogenesen, av moget kaledonisk och ungt alpin ålder. Sålunda är Oslo en av naturen själv anvisad mötesplats för den nordiska geologin — med den extra recentkrydda som medföljer ett seismiskt frekvensmaximum.

Herr President! Vår fulla och säkra övertygelse är att när Ni, Herr President, slår klubban i bordet för att på allvar öppna förhandlingarna vid det andra nordiska geologvintermøtet, Oslofältet kommer att svara — instämma med ett lagom avpassat, icke förhandlingsbrytande, men för geologerna stimulerande och för lekmännen respektinjagande jordskalv.

Spelet kan börja.

Abstracts.

Asklund, B.: *New observations from the central part of the fold-mountain chain in Sweden.*

Nya iakttagelser från mellersta fjällkedjan i Sverige.

Kartläggning kring Ströms Vattudal, Jämtlands län, har visat, att det under Strömskvartsitskollan kan utskiljas åtminstone två kambrosilurskollor, varav den västra är underlagrad av överskjuten eokambrisk kvartsit. Det autoktona urbergssparagmit-kvartsit-området uppvisar rik stratigrafisk utveckling. En ny lokal av tillit har anträffats. Den liknar den norska Moelvstilliten. En övre tillithorisont av boulder-clay typ tillhörande den eokambriska kvartsitens lagerserie har anträffats 1955. Den överlagras med vinkeldiskordans av marint (mellan?) kambrium.

Berthelsen, A.: *Field-observations of gabbro-anorthositic, and dioritic rocks of the Sukkertoppen and Godthåp districts.*

Feltiagtagelser over gabbro-anorthositiske, anorthositiske og dioritiske bjergarter i Sukkertoppen og Godthåb distrikter.

Gabbro-anorthositiske til anorthositiske bjergarter (An 45—85) synes dannet *synkinematisk* på bekostning af skarnrige amfibolitlag i kontakt med Al-rige bjergarter under granulitfacies betingelser. *Senkinematiske* replaceringsprocesser har i lithologisk og strukturelt betingede foci ført til dannelsen af dioritiske til ægte anorthositiske (An 33—45) homogene bjergarter. *Postkinematiske* gange og apliter antyder overgange til palingenetiske tilstande på større dyb.

Bondam, J.: *Gabbro-anorthosites formed by retrograde metamorphism from the Fredrikshaab district, Southwest Greenland.*

Retrogradt omdannede gabbro-anorthositer fra Fredrikshaab District, Sydvest Grønland.

Feltiagttagelser synes at vise, at gabbro-anorthositerne er facielt afvigende fra de øvrige gneisserier i området. Gabbro-anorthosit-horisonter forekommer i en hornblendeførende, granodioritisk gneisserie, ledsaget af diorit og dioritiske gange.

Der omtales en række petrogenetiske iagttagelser i forbindelse med fænomener indenfor gabbro-anorthosit-horisonterne.

Byström, A. M.: *Clay-minerals in Ordovician bentonite beds in Scania.*

Lermineralen i ordoviciska bentonitlager i Skåne.

Pågående undersökningar av borrkärnsprover från ordoviciska bentonitlager i Skåne visar att lermineralen till största delen består av blandskiktmineral av illit- montmorillonittyp med mycket låg halt av svällande skikt. En jämförelse göres med lermineralen från Kinnekulles bentonitlager, varifrån två olika typer av liknande mineral tidigare beskrivits. Lermineralen i Skånes bentonitlager påminner närmast om dem, som beskrivits av Weaver från förekomster i Pennsylvania, U.S.A.

Littr.: Byström, A. M. (1954) «Mixed layer» minerals from the Ordovician bentonite beds at Kinnekulle, Sweden. Nature *173*, 783. Weaver, C. E. (1953) Mineralogy and petrology of some Ordovician K-bentonites and related limestones. Geol. Soc. American Bull. *64*, 921.

Carstens, H.: *Metamorphism of the hyperites of western Norway.*

Metamorfosen av de vestnorske hyperitter.

Studier av omdannelsens art, fordelingen av omdannete hyperitter m.m. viser at hyperittenes metamorfose begynte og tok ulike retninger allerede under det senmagmatiske stadium.

Litt.: T. Gjelsvik: Metamorphosed Dolerites in the Gneiss Area of Sunnmøre on the West Coast of Southern Norway. N.G.T. *30*, 1952.

De Geer, E. H.: *New datings with examples of De Geer's chronology.*
Nya dateringar med exempel ur De Geer's kronologi.

1. A cyclic structure in macro- and microvarves. (G. De Geer 1940, Figs. 21, 22, Pl. 50).

2. F. Firbas' (new) determinations: Oldest Dryas Ia, Bölling thermal Ib, Older Dryas Ic, Older Alleröd IIa, Younger Alleröd IIb, a C 14 dating of the Bölling thermal to 13 300—12 300 B.P., all quite congruous with iceborder lines dated by G. De Geer, as exactly 13 300—12 300 occurred the first rapid ice-recession, forming the Rörum- and Scania-Kalmar ice lakes, finished by a morainic halt, dated by varves from Uddevalla—Gothenburg—NE Scania—Bleking—Kalmar (E. H. De Geer 1954, GFF 76: 304—305, F. Firbas 1955, Die Naturwissenschaften 42: 18: 509).

3. Chert may have arrived into the Oslo region during the Bölling thermal stage, by iceberg transport through Øresund—Kattegat.

Dietrichson, B.: *Comparative survey of the lower and the upper Jotun eruptive nappes.*
Sammenliknende undersøkelse av det undre og det øvre Jotuneruptivdekke.

Bearbeidelsen av materialet fra Østjotunheimen og forgårdene viser at begge dekker representerer gravitativt differentierte anortosit-mangerit-charnockit-rekker. I det øvre dekke er anortosit-bytownit-leddet — våre *labrador- og bytownit-felser* — *ikke utviklet*, mens det danner det mest karakteristiske ledd i det undre dekkes erosjonsrester. Hvor de øvrige ledd i det undre dekkes differensiasjons-serie opptreder, viser de uttalt autometamorfe trekk og plastisk deformasjon til «granulithabitus», i motsetning til det øvre dekkes «gabbrohabitus», hvor bergartene nærmest har eugranittisk struktur.

Litt.: V. M. Goldschmidt: Geol. Petr. Stud. Hochgeb. südl. Norwegens. IV Übersicht Eruptivgesteine im Kaled. Geb. Vid. sk. selsk. skr. 1916.
Gjelsvik, T.: Anorthosittkomplekset i Heidal. N.G.T. *26*, 1947.
Dietrichson, B.: Spessartite and Pseudotachylite — — — East-Jotunheimen. N.G.U. *191*, 1955.

Dons, J. A.: *The occurrence of «coal-blende» in south-east Norway.*
Kullblendens opptreden i S.-E.-Norge.

Det er gjort nye funn av kullblende — et «mineral» i gruppen anthraxolite (Dunn, Fischer, Am. Journ. Sci. *252*, 1954), thucholite (Grip, Ödman. S.G.U. Ser. C. *464*, 1944), carbonite (Mueller. Comptes Rendus 19 session, Congres. Geol. Int. Alger. 1952, Sect. XII, Fas.

XII, 1954) etc. Tidligere norske beskrivelser: (Neumann. N.G.U. *165*, 1944, N.G.T. *18*, 1939; Kristoffersen. N.G.T. *18*, 1939). Det fremlegges nye analyser som bl.a. viser vanadium-innhold (og i ett tilfelle uraninnhold). Paragenese og genese vurderes.

Eckermann, H. von: *The age of the Alnö eruptive complex.* (*Read by F. E. Wickman*).

Alnö-eruptivets ålder.

Geologiska iakttagelser och en i samarbete med professor F. E. Wickman utförd U-Th-Pb-bestämning på pyrochlor visar att Alnösöviten icke kan vara äldre än eokambrium men möjligen yngre. Isotopbestämning av Pb återstår att utföra.

Litt.: The Alkine District of Alnö Island. S.G.U. Ser. ca, *36*, 1948.

Frediksson, K.: *Extra-terrestrial particles in deep-sea sediments* (*Read by K. F. Alm.*)

Extraterrestriska partiklar i djuphavssediment.

I magnetiskt material extraherat ur sedimentproppar från Svenska Djuphavsexpeditionen har försök gjorts att identifiera och kvantitativt bestämma olika kosmiska partiklar. Den brett upplagda undersökningen har hittills endast omfattat svarta magnetit eller magnetit — järn kulor (Sir John Murray's «cosmic spherules») med en diameter av 30—250 my. Mikrobilder av dessa kulor, även i polersnitt, visas och de första kvantitativa resultaten diskuteras.

Litt.: Buddhue, J. D.: Meteoritic Dust, 1950 (Univ. of New Mexico Press). Pettersson, H.: Shooting Stars, Festskrift för T. E. Broström, Göteborg 1955. Taivo Laevastu & Otto Mellis, Transact. Amer. Geophysical Union, *36*, no. 3, 1955, pp. 385—389. Bruun, A. Fr., Langer, E. & Pauly, H.: Deep-sea Research, Vol. 2, 1955, pp. 230—246.

Föyn, S.: *Stratigraphy and tectonics south of Laksefjorden, Finnmark.*

Stratigrafi og tektonikk sör for Laksefjorden, Finnmark.

Undersøkelsen ble utført sommeren 1955. Bergartene i det undersøkte område viste seg å tilhøre i det vesentlige den tillittførende, yngre del av den eokambriske lagrekke. Som i Tana-området er det to tillitthorisonter. Tykkelsen av tillittene og den mellomliggende skifer- og sandsteinsserie varierer primært. Det tektoniske bilde er preget av overskyvninger, med bl.a. grunnfjellsflak skjøvet over den tillittførende avdeling.

Litt.: Vogt, Th.: Undersøkelser sommeren 1927. N.G.U. Årbok 1924—28. N.G.U. nr. 133, p. 62—63. Oslo 1929.

Føyn, S.: The eo-cambrian series of the Tana district, Northern Norway, N.G.T. *17*, p. 65—163. Oslo 1937.

Gavelin, S.: *On variations in the stable C-isotopes in carbon from some Pre-cambrian and Caledonian limestones and schists, and their significance.*

Om variationerna av de stabila kolisotoperna i kol från några prekambriska och kaledoniska karbonatstenar och skiffrar och deras signifikans.

Som ett led i de undersökningar av isotopsammansättningen i kol från olika miljöer, vilka sedan en tid bedrivits i Stockholm, ha C^{12} C^{13}-kvoten bestämts inom urbergsområden i norra Sverige vilkas geologiska byggnad genom nya karteringsarbeten äro förhållandevis väl kända. Variationerna i kvotvärdena ha korrelerats med växlingar i metamorfoser av olika slag och med variationer i ursprungliga sedimentationsmiljøer.

Litt.: Kapitlet «Carbon» i K. Rankama: Isotop Geology. London 1954, p. 181—234.

Gjessing, J.: *Some remarks on ice-erosion and the sculpturing of fjords and valleys.*

Noen ord om iserosjon og fjord — dal — utforming.

Elveerosjonen på landoverflaten er avhengig av horisontalavstanden til erosjonsbasis. Preglaciale daler munnet ved den ytre kyst, forkastningslinjene. Noen generelle betraktninger over isens formning av tverr- og lengdeprofiler i daler, og den vekslende glacial- og fluvialerosjon i glacial- og interglacial-tider. «Dal i dal»-utdannelse: den yngre dal er ved («tilbakegående») glacial-(og fluvial-) erosjon skåret inn og ned i bunnen av den glacialt påvirkende preglaciale dal. — Noen eksempler på dalender (store trinn i lengdeprofilet ved den indre ende av den yngre dal). Den mest typiske dalendeform antas å være glacial. Fluvial erosjon kan ha betydd meget for innskjæringen av den yngre dal idet avstanden til erosjonsbasis er blitt sterkt forkortet etter glacial overfordypning, fjorddannelse.

Siste sammenfatning av tidligere oppfatninger, litteraturliste: Holtedahl, O.: Norges geologi, N.G.U. 164, 1953.

Grip, E.: *The nickel deposit at Lainijaur in the Skellefte mining district.*

Nickelförekomsten Lainijaur i Skelleftefältet.

En nickelförande gabbro har trängt upp genom en spricka i botten av en sedimentsynklinal och brett ut sig phakolitformigt. Nickelmalmen ligger som linjaler på båda sidor om gabbrogången i phakolitkroppens liggande. Bergarter, strukturer och malmens genesis diskuteras.

Halden, B. E.: *Interesting mineral- and rock-finds from field investigations concerning known occurrences of hazel and other gypsophilous plants*

Märkliga mineral- och bergartsfynd från markundersøkningar invid kända förekomster av hassel och andra «kalkväxter».

Sambandet mellan växtart och mineraliskt substrat, direkt eller vid perkolering, är ett gammalt, delvis ouppklarat, delvis (och främst av fältbotanister) förvanskat problem.

Asplenium adulterinums förekomst enbart på olivinserpentingrund är sedan länge fastställd. *Asplenium Ruta-muraria* på förmodad gnejsgrund ledde till föredragandens fynd av *kalkgranit* (se Svensk Botanisk tidsskrift 1950, p. 535). Hasseln resp. andra kalkväxter har avslöjat förekomster av bl.a. anorthosit och prehnit, ävensom av dolda diabasförekomster i bottnarna av ett par klippkanjons. Därtill har en intressant men ännu ej fullt utredd granittyp spårats med hassel som ledväxt, förutom snart ett hundratal lokala kalkstens- resp. skalbanksförekomster. Jutulhoggets botaniska problem ev. ett mineralogiskt-kemiskt. — Dessa frågors plats inom geologien faller alltså inom prospekteringen.

Holmsen, P.: *The basal beds of the hyolithus zone in Vestfinmark.*

Hyolithus-sonens basale lag i Vestfinnmark.

I forbindelse med de to siste somrers geologiske kartlegging av Vestfinnmarks prekambrium, som en del av NGU's markarbeidsprogram, er hyolithus-sonen gått opp fra Lodiken i øst til fylkesgrensen mot Troms i vest. Mens der tidligere kun var kjent at hyolithussonens basalkonglomerat hviler direkte på prekambrium, viste det seg at der flere steder, særlig omkring Carajavre, ligger en liten eokambrisk serie under basalkonglomeratet, bl.a. et morenekonglomerat.

Litt.: Holtedahl, O.: Bidrag til Finnmarkens geologi, N.G.U. *84*, 1918, p. 28—34, 118, 123 ff.

Holtedahl, H.: *On sediments in the Norwegian Sea.*

Litt om Norskehavets sedimenter.

Seks bunnpropper på vel en meters lengde ble tatt i Norskehavet mellom Island og Norge fra dybder mellom 1000 m og ca. 3 000 m. Den nedre del av fire av proppene består av grått, usortert leir med stein, typisk for glacial-marine sedimenter. Lenger opp øker sedimentets finhet og steininnholdet forsvinner, tydende på en klimaforbedring Foraminiferinnholdet viser en markert økning. En sone med steinførende leir tyder på en forværring av klimaet. Øvre del av proppene (under 1 500 m) består av foraminifermergel med $CaCO_3$ innhold på opptil 40 %.

Litt.: Schmelck, L. The Norwegian North-Atlantic Expedition 1876—1878. II On Oceanic Deposits. Chra. S. 1—71.

Horn of Rantzien, H.: *Charophytes — guide-fossil for the correlation of fresh-water deposits.*

Charofyter — ledfossil för korrelation av sötvattenavlagringar.

Fruktifikationer, s.k. gyrogoniter, polära kroppar med spiralstruktur och av 0.3—1.5 mm diameter, av charofyter, en grupp komplicerat byggda, kalkavsöndrande sötvattensalger, har såsom fossil påträffats från och med översta gotlandium. Genom snabb fylogenetisk utveckling, vidsträckt horizontell utbredning och hög frekvens på därför lämpade lokaler torde de komma att få betydelse vid korrelation av särskilt mesozoiska och konozoiska sötvattensavlagringar. Pågående undersökningar synes i hög grad bekräfta charofyternas användbarhet som stratigraphic markers.

Ref.: H. Horn of Rantzien: Middle Triassic Charophyta of South Sweden. Opera Botanica, I (2): 1—83. 1954.

H. af. Rantzien: Genera of fossil Charophyta — an annotated check-list. Micropaleontology, 2 (1) Jan. 1956 (under tryckning). K. Mädler, Zur Taxionomie der tertiären Charophyten. Geol. Jahrb. 70, 265—328, 1955.

R. E. Peck, Fossil Charophytes. Bot. Rev., 19, 209—227, 1953.

Høeg, O. A.: *Double walls in fossil megaspores.*

Dobbelt vegg hos fossile megasporer.

(På vegne av M. N. Bose, S. Manum, og O. A. Høeg).

Noen av megasporene i Glossopteris-floraen i Kongo har dobbelt vegg (først iakttatt av Bose). Den ytre sprekker under macerasjon og kan også fjernes ved disseksjon. Den indre danner et sporeliknende legeme omtrent halvt så stort som hele sporen. Mikrotomsnitt viser at de to veggene henger sammen på proksimalsiden. Om det indre sporelegeme var blitt funnet fritt, ville det bli tatt for å høre til en helt annen plante enn hele sporen. Litteratur viser at liknende dobbeltvegg er sett før, uten å kunne tydes.

Johansen, E.: *Stone-Age dwelling-places and shore-line measurements.*

Stenalderboplasser og strandlinjemålinger.

Stenalderens boplasser er blitt viktige holdepunkter både når det gjelder datering og høydebestemmelser av strandlinjer. Dette fordi man har gått ut fra at boplassene har ligget ved sjøen. For å gi holdepunkter må det foreligge mange boplasser i et felles nivå innenfor et lite område. Et par års undersøkelser og praktiske forsøk med rullet flint, viser at selv ikke den slags kant-slitt boplassmateriale er et sikkert bevis for kontakt med sjøen.

Kahma, Aa. *On K-A age determinations of some Finnish granites and gneisses.*

Om K-A-åldersbestämningar av några finska graniter och gnejser.

Resultaten av 28 K-A-åldersbestämningar gjorda av 10 finska graniter och gnejser presenteras. De erhållna värdena gruppera sig i två postkinematiska granitgrupper med respektiva åldrar av 1400—1450 ± 100 miljoner år och 1770—1860 ± 120 m.å. Dessa granitgruppers förhållande till den karelska och svekofennidiska orogenin diskuteras.

Litt.: H. A. Shillibeer & R. D. Russell: The Potassium-Argon Method of Geological Age Determination. Can. Journ. of Physics *32*, p. 681—698, 1954.

G. J. Wasserburg & R. J. Hayden: A^{40}-K^{40} dating. Geochim. et Cosmochim, Acta *7*, nos. 1/2, p. 51/60, 1955.

Lindström, M.: *On the Caledonide folding at Torneträsk.*

Om de kaledoniska veckningarna vid Torneträsk.

Strukturella data har innsamlats i två områden med fjällberggrund och bearbetats grafiskt — statistiskt med Schmidtnät. Det visar seg, att flera distinkta, tydeligen för båda områdena gemensamma deformationer har ägt rum. Dessa kan med någon säkerhet tidsbestämmas i förhållande till varandra.

Ljunggren, P.: *The «Mull-ore» at Värmlands Taberg.*

Mullmalmen vid Värmlands Taberg.

Mineralsammansättningen på mullmalmen och det lervittrade sidoberget har undersökts med differentialtermisk analys och röntgenanalys. Järnmalmen har övergått i goethit; vissa data tyda på att det finnes två modifikationer av goethit. Det magnesiarika skarnet har omvandlats till antigorit. Sura sidobergarter av gnejs och leptittyp ha kaoliniserats.

Litt.: Geijer, P. & Magnusson, N. H.: Mullmalmer i svenska järngruvor. S.G.U. Ser. C, No. *338*, 1926.

Machatschki, F.: *The structure of chain silicates.*

Oppbygningen av bånd-silikater.

Det første innblikk i bånd-silikatenes konstitusjon ble oppnådd i 1928 ved bestemmelsen av diopsidens struktur (Warren og Bragg). Senere fulgte amfibolenes struktur, og i to etapper strukturen hos Chrysotil med sin «Schichtröhrchenstruktur» (pseudofiberstruktur). I de siste år er strukturene hos tallrike fiber-mineraler blitt bestemt (Bergkork, Berglær, Xylotil, Palygorskit, Attapulgit og Sepiolith). (Oversatt fra tysk).

Magnusson, N. H.: *The classification of the pre-Cambrian rocks of Sweden.*

. Det svenska urbergets indelning.

Kort meddelande rörande de svårigheter som uppställandet av ett för hela Sverige giltigt ålders-schema bjuder.

Mellis, O.: *Some proposals for the simplification of crystallographic and crystal-optic terminology.*

Några förslag till förenkling av kristallografisk och kristall-optisk terminologi.

Koordinataxlarna i kristaller bör i stället för a, b, c, betecknas med x, y, z.

De i kristalloptiken sedvanliga beteckningarna för ljusbrytningsindices n_ω (n_o) och n_ε (n_o) bör ersättas med n_α , n_β (n_p . n_m) för optiskt negativa och med n_γ, n_β (n_g , n_m) för optiskt positiva enaxliga kristaller. Dessa, för en- och tvåaxliga kristaller enhetliga beteckningar, ha sedan 1953 använts av A. G. Betechtin (Lehrbuch der Mineralogie, Berlin 1953).

Neumann, H.: *Preliminary report on the rhenium content in Norwegian molybdenites.*

Foreløpig meddelelse om Rhenium-innholdet i norske molybdenglanser.

Orienterende undersøkelser av norske molybdenglanser viser at deres Re-innhold varierer mellom størrelsesordenene 0.X % og 0.000X %. Variasjonene er store innen grupper av beslektede forekomster og endog innen en og samme forekomst.

Oftedahl, Chr. 1. *On the Grong-culmination and its nappes.*

Om Grongkulminasjonen og dens skyvedekker.

Kartene etter statsgeolog Foslie viser at Grongkulminasjonen består av to skyvedekker med hver sin kambro-silur-serie, underst Oldengranitt med basallag av kvartsitt, kalk og fyllitt, derover granitt og porfyr («leptitt») med påhvilende «Trondhjems-kambrosilur» i SV, østlig Grongfacies i NØ. Den sannsynligste gruppering av Grongfeltets serier i skyvedekker blir presentert. Denne stemmer i det vesentlige overens med det på Göteborg-møtet fremsatte forslag.

2. *The geology of the Joma sulphide deposit.* Joma kisforekomsts geologi.

På grunnlag av Fosslies og egne feltstudier gis en oversikt over forekomstens geologiske stilling. Forekomsten ligger i grønnsten i en mineralisert sone som kan følges over 4 km. Selve malmen ligger hvor denne sone bøyer fra Ø—V til N—S. Malmen er oppdelt i en rekke linseformete linjaler som følger foldningsaksen for en fleksurartet foldning.

Oftedal, I.: *Remarks on the formation of certain endogene enrichments of elements.*

Bemerkninger om dannelsen av visse endogene element-anrikninger.

Data som er publisert (N.G.T., b. 33, 153—161, 1954) og senere supplert, tyder bl.a. på følgende:

Mens grunnfjellsgraniters kalifeltspater (mikroklin) kan krystallisere med betydelige blygehalter — opp til 100 g/t og mer —, kan ekte magmabergarters kalifeltspater (ortoklas) ikke oppta merkbare mengder bly. Oslomagmaenes opprinnelige (ubetydelige) blygehalter synes nesten kvantitativt å være drevet ut i sidebergartene. Det antas derfor at meget store blyforekomster må kunne dannes i omegnen av blyrike palingene granitmassiver (f. eks. Østfoldgraniten, som gjennomsnittlig synes å holde minst 50 g/t Pb), hvis disse blir utsatt for en sterk temperaturstigning, f. eks. ved orogen nedpressing.

Observasjonsmaterialet er ennå temmelig sparsomt, men blir etter hvert supplert med nye data.

Pabst, A.: *Remarks on the deformation of crystals.*

Bemerkninger om krystallenes deformasjon.

Bergartenes deformasjon foregår til dels ved mekanisk deformasjon av krystallindivider. I noen tilfelle er dannelse av mekaniske tvillinger (twin gliding) hovedmekanismen. Krystallografiske betraktninger förer til en bedre forståelse av fenomenene. En kan, for eksempel, skille mellom geometrisk mulige og umulige tvillingsmekanismer, undersøke texturene i deformerte krystaller og, hvis vedkommende krystallstrukturer er kjente, beskrive atomforskyvninger som forekommer ved deformasjonen.

Litt.: Pabst, A.: Transformation of Indices in Twin Gliding. Bull. Geol. Soc. Am. *66*, pp. 897—912, 1955, hvor der også henvises til videre litteratur.

Padget, P.: *The Precambrian geology of West Finnmark.*

Vest-Finnmarks prekambriske geologi.

Hovedtrekk i N.G.U.'s systematiske kartlegging av de prekambriske bergarter i Vest-Finnmark er lagt frem. Lagdelte bergarter er vesentlig: kvartsitt, grønnstein, grønnskifer, glimmerskifer (tidligere kalt «den vestlige supraskrustale serien»). Disse forekommer i parallelle soner med strøk NS. En viktig ledehorisont er et fuksittholdig konglomerat med granittboller. Lite metamorfosert argillitt, «siltstone» og kvartsitt opptrer langs fjellryggen Caravarre. I øst, syd og sydøst er migmatisering nokså vanlig. Flere forkastninger er påvist.

Litt.: Holtedahl, O.: Bidrag til Finnmarkens Geologi. N.G.U. *84*, 1918.

Regnéll, G.: *On bolboporites.*

Om Bolboporites.

I under- och mellanordoviciska kalkstenar företrädesvis i Ostbaltikum, Sverige och Norge uppträda små konformiga kroppar, som av Pander (1830) benämndes *Bolboporites*. Hur *B*. skal tolkas, har varit en omstridd fråga, som nog fortfarande får lämnas delvis öppen. Klart är dock, att *B*. hör till ekinodermerna. Enl. talarens mening synes något samband finnas mellan *B*, och cystoidésläktet *Cheirocrinus*, enl. Eltysheva (1955) äro bolboporiterna taggar från dorsalsidan av asteroidéer liknande den recenta *Oreaster*.

Litt.: Eltysheva, R. S.: 1955. Bolboporiti. — Voprosi paleontologii. 2. S. 136—147. Leningrad. (Endast ryska).

Jakovlev, N. N.: 1921. *Bolboporites*, its organization and appertenance to the Hydrozoa. — Ann. soc. paléontol. Russ. 3, S. 1—10. Leningrad. (Ryska m. eng. sammanfattning).

Wanner, J.: 1920. Über einige palaeozoische Seeigelstacheln. (*Timirocidaris* gen. nov. und *Bolboporites* Pander). — Kon. akad. wet. Amsterdam proc. sect. sci. 22:2 S. 696—712. Amsterdam.

Rosendahl, H.: *Fundamental problems in the hydro- and cryosphere.*

Fundamentale problem i hydro- og kryosfæren.

Emnet for foredraget var: Hva er den sterkest formende agens i et nediset land? Svaret er at det er vatnet under isen, og det virker ikke så meget ved mekanisk sliping med medførte partikler, korrasion, men hovedsaklig ved kavitationserosien, en molekylarfysisk effekt, som i geologien kalles korrosion. Dette molekylarfysiske fænomen har vist sin virkning på turbiner og blir nu gransket av fysikere og ingeniører. Det viser en så stor likhet med jettegrytefænomenet, at det neppe er noen tvil om, at også jettegrytene er utsvarvet ved kavitation. Det er nu en fysisk kjent effekt, og ordet kavitationserosion bør derfor erstatte det noget uklare geologiske ord evorsion. De glaciale sjøer i fast berg må være korroderte av vatnet under isen, f. eks. Mjøsa, som ble korroderet ned til 600 m under havflaten av vann under trykk fra noen tusen m tykk is. Våre daler er en serie daltrinn, f.eks. i Gauldalen ovenfra: Ålen, Haltdalen, Singsås, Støren med bergtreskler (eider) mellom. Serien er bestemt av en kombinasjon av petrologiske årsaker og den synkende snelinje ved inngangen til hver ny istid; men arbeidet er utført av vannet.

Rosenqvist, I. Th.: 1. *Granulite, mangerite, eclogite.*

Granulitt, mangeritt, eklogitt.

Etter studier i Vest-Europa, Heidal og Sachsen—Bøhmen, har foredragsholderen fått den oppfatning at de bergarter som vanligvis

betegnes som Bergen—Jotun bergarter representerer *forskjellige* magmatiske og metamorfe bergarter, karakterisert ved at de alle har fått sitt preg eller deler av sitt preg under forhold svarende til granulitt-eklogitt facies. Mineralinnholdet i mange vestnorske gneiser anses som et diaftoretisk trekk.

2. *The weathering of clays.* Leirers vitring.

De ungkvartære skandinaviske marine leirer er tidligere inndelt i fire grupper. I. De normalt konsoliderte, uendrete salte leirer. II. De normalt konsoliderte, utlutede leirer (kvikkleirene). III. De vitrede leirer. IV. De rekonsoliderte skredleirer. I dette fordrag behandles gruppe III. Ved hjelp av kjemiske og mineralogiske undersøkelser av leirer fra «tørrskorper» og rundt vertikalt-stående dype rotrør og sprekker er det vist at vitringen kan deles i to uavhengige komponenter; 1.: Ren hydrolyse, hvorved dioktaedriske og trioktaedriske glimmre delvis omdannes til hydronium glimmre, «illitter», pluss KOH. Denne reaksjon er temperaturavhengig, men innebærer ingen oksydasjoner. Den annen vitringsgruppe omfatter dannelse av montmorillonide mineraler fra de di- og trioktaedriske glimmermineraler og omdannelse fra trioktaedriske til dioktaedriske mineraler Disse prosesser kan kun foregå ved tilgang av oksydasjonsmidler (surstoff). De er de viktigste i tørrskorpen.

Saare, E.: *Heat conductivity in certain soil profiles.*

Värmeledningsförmågan hos några markprofiler.

Värmeledningsförmågan hos jordarterna har bestämts med en icke stationär värmeström från en lång cylindrisk värmekälla. Apparaten består av en sond, som uppvärmes med elektrisk strøm. Sondens temperaturändring mätes med termoelement och en registrerande elektronisk potentiometer. Sonden nedföres i jorden och man prövar sig fram till en lämplig effekt för dess uppvärmning. Efter ca. 10—14 minuter bör temperaturen i sondens kontaktyta med omgivande material, dvs jord, stiga ca. 10° C. Ur den erhållna temperaturstegringskurvan bestämmes grafiskt jordartens värmeledningskoefficient. Metoden har tillämpats vid fältförsök för undersökning av värmeledningsförmågan hos några markprofiler där jordarterna och fukthalt varierar.

Sahama, Th. G.: *Potassium-rich nepheline and kalsilite in the volcanic lavas of the Nyirangongo district of the Belgian Congo.*

Kalirik nefelin och kalsilit i Nyiragongo områdets vulkaniska lavor i Belgisk Congo.

Den aktiva vulkanen Nyiragongo samt den omgivande lavaplateaun i Nord Kivu (Belgisk Congo) karakteriseras av fältspatfria melilit-nefeliniter samt leucit- och nefelinbasalter. Nefelinströkornen i vissa lavaströmmar är extremt kalirika med över 40 mol. % kalikomponent. I andra lavor inom området förekommer kalirik nefelin i homoaxial sammanväxning med kalsilit, delvis i form av pertit med nefelinstrimmor i kalsilitbas. Förekomsten diskuteras på grund av det Tuttle-Smith'ska fasdiagrammet för systemet nefelin-kalsilit.

Litt.: Sahama, Th. G. Parallel growth of nepheline and microperthitic kalsilite from North Kivu, Belgian Congo. Ann. Acad. Scient. Fennicae, Ser. A III, No. *36*, 1953.

Smith, J. V. & Sahama, Th. G. Determination of the composition of natural nephelines by an X-ray method. Min. Mag., Vol. XXX, p. 439, 1954.

Spjeldnæs, N.: *The boundary between the Ordovician and the Silurian in the Oslo Region.*

Grensen Ordovicium—Silur i Oslofeltet.

Nødvendigheten av å trekke grensen i overensstemmelse med typeområdet understrekes. Den faller i Oslofeltet mellom sone 5b og 6a. Allerede Kiær (1902) viste at etasje 5 var foldet under avsetningen, og nyere undersøkelser har vist at det er en tydelig vinkeldiskordans mellom ordovicium og silur i Oslo-Akers området. Den underste del av siluren (subsonen med *Climacograptus scalaris normalis*) er bare utviklet i den sydligste del av Bunnefjorden, mot nord og vest er det stadig yngre lag av siluren som en finner i kontakt med ordovicium.

Litt.: Kiær, J. 1902. Etasje 5 i Asker. N.G.U. *34*, pp. 1—111.

Ström, K.: *A broad abrasion-platform in the outer Oslofjord.*

En bred abrasjonsplatform i Ytre Oslofjord.

Ved den lite eksponerte N pynt av RP-konglomeratøya Store Sletter er det en ca. 60 m bred abrasjonsplattform nøyaktig i det nåværende havnivå. Den må markere en langvarig stans i landhevingen, vanskelig å tidfeste, om den i de senere år observerte endring i havstanden (Oslo — 3.6, Nevlunghavn — 1.8 mm p. a.) må tydes som tilsvarende landheving gjennom lengre tidsrom.

Litt.: Brøgger, W. C.: Senglaciale og postglaciale nivaaforandringer i Kristianiafeltet. N.G.U. *31*; Størmer, L.: Geology of the Southern Part of the Oslofjord. N.G.T. *15*, 1935. Beretning om Norges Geografiske Oppmålings virksomhet 1951, Oslo 1952.

Sørensen, H.: *Anorthosite from Greenland.*

Anorthosit fra Grønland.

Anorthositiske bjergarter bestående af bytownit og hornblende (samt clinozoisit) optræder i Sydvestgrønland som lag, der kan være ret mægtige, som er foldet sammen med de omgivende bjergarter

(f. ex. glimmerskifer og amfibolit), og som af og til har indeslutninger af hornblenditer. Anorthositen findes i amfibolitfacies-kompexler, men sammen med relikter af granulitfacies-bjergarter, således at det ser ut til, at hele komplexet (anorthositerne indbefattet) tidligere har været udsat for granulitfacies-betingelser.

Vokes, F. M.: *Copper sulphide deposits in the Birtavarre district, Troms.*

Kopper-sulfid forekomster i Birtavarre området, Troms.

Recent investigations by N.G.U. have given a fairly complete picture of the chalcopyrite-pyrrhotite-(sphalerite) deposits of the area. They occur as gently-dipping plates of extremely variable thickness (0—3 m) elongated along the lineation direction of the surrounding Caledonide schists. They occupy a series of minor, brecciated thrusts in the Ankerlia Schist series underlying a thrust-nappe in the Caledonide orogenic zone. The thrusting occurred as a late phase of the orogeny after the main regional metamorphism, and it is suggested the ores came up along the thrust-planes from a source deeper in the geosyncline.

Minutes from the Conference on Eocambrian, Extent, and Subdivision.

O. Holtedahl:

Til den 20. internasjonale geologkongress som skal avholdes i Mexico i 1956 skal det utarbeides et «symposium» over *kambrium* i de forskjellige strøk av jorden, med henblikk på bl.a. å fastsette en nedre grense for det kambriske system. For en drøftelse av denne grense er det nødvendig også å ha en oversikt over de nærmest under det fossilførende kambrium liggende, og til kambrium nær knyttede, lagrekker. Jeg har fått i oppdrag å utarbeide en oversikt over «eokambrium» på den skandinaviske halvøy.

Personlig har jeg som de fleste norske geologer anvendt denne betegnelsen i den opprinnelige, vide betydning. Selv om det på formelt grunnlag kan rettes innvendinger mot en slik anvendelse idet de eldre av de avsetninger det her dreier seg om, må antas å tilhøre et tidsrom som ligger atskillig bakenfor den kambriske periode, slik denne gjerne er fiksert. Det har også fra flere hold kommet forslag om å benytte «eokambrium» i en mer innskrenket betydning. Spørsmålet ble diskutert på Norsk Geologisk Forenings møte i november og det er naturlig at det tas opp igjen her ved det nordiske geologmøte idet det jo dreier seg om forhold av interesse ikke bare for norske og svenske geologer, men også for danske som kommer i berøring med det i sin Grønlandsforskning.

Betegnelsen eokambrium ble foreslått på trykk av W. C. Brøgger i 1900 men han hadde alt et år tidligere benyttet det i sine forelesninger over Norges geologi. Det var da først og fremst Mjøs-lagrekken som her kom med, en lagrekke som nettopp på den tid var blitt nøyaktig utredet gjennom Th. Münsters undersøkelser for kartbladet Lillehammer. Både Brøgger og Münster oppfattet disse avsetninger som aller eldste kambrium.

Det dreidde seg her om dannelser som hørte hjemme i Kjerulfs «sparagmitt-formasjon», en betegnelse som var blitt oppstillet (på det skandinaviske naturforskermøte i København) i 1860. Lagrekken inngikk som etasje 1 i Kjerulfs etasjesystem og ble antatt å være av «takonisk», dvs. kambrisk alder. Kjerulf delte i sine senere publikasjoner sp. f. (eller «sparagmit-fjellet», henholdsvis «sparagmitt-kvartsfjellet» som han nå kalte de lagmasser det her gjaldt, for å markere at det dreiet seg om ikke-fossilførende lag) i en undre del, sparagmitter og Birikalk (1a) og en øvre, med kvartssandstein (hit regnet han for øvrig også Trysil-sandsteinen) i nær tilknytning til Olenellusførende skifer, og sammen med denne kalt 1b. Den sistnevnte gruppe hørte til «primordial» (kambrium), den eldste var av «azoisk» alder (han taler i «Udsigt over det sydlige Norges geologi», 1879, s. 128, om «et azoisk, med bruddstykkebergarter opskiktet grundfjeld»).

Vi skal ikke i dette referat gå i enkeltheter med hensyn til den historiske utvikling senere, men henvise til oversikten i nevnte symposium. Bare noen hovedpunkter skal nevnes. Törnebohm henførte (se bl.a. hans store arbeide fra 1896) sparagmitt-formasjonen til sin Sevegruppe for hvilken han antok en algonkisk alder. I 1916 diskuterte J. Kiær sparagmitt-formasjonens alder i forbindelse med sine studier av de underkambriske fossilførende lag på Ringsaker og hadde som konklusjon at lagrekken naturlig burde regnes til kambrium. I 1924 fremhevet Vogt, på grunnlag av studier i Mjøs-traktene, at det er en markert stratigrafisk grense mellom det fossilførende kambrium og «sparagmitt-systemets» lagrekker og at disse burde regnes til prekambrium (algonk). Etter studier på svensk område foreslo i 1935, Asklund som også regnet lagrekkene til algonk — at man (liksom for så vidt alt Kjerulf hadde gjort) skulle skille ut en (yngre) kvartsitt-skifer avdeling fra en eldre sparagmitt-formasjon med grå og røde sparagmitter (samt karbonat-bergarter m.v.). Betegnelsen eokambrium burde begrenses til den øvre avdeling. I 1942 foreslo Kulling betegnelsen «Varanger-istiden» for den nedisningsperiode som tillittene på den skandinaviske halvøy og i de arktiske strøk (m.v.) forteller om. I et arbeide om lagrekkene i Finnmark fremhever Rosendahl, 1945, at betegnelsen eokambrium, i betydning tidligste kambrium, bør anvendes bare for lag fra tillittene og oppover. For den før-tillittiske lagrekke, som må regnes til prekambrium, kunne betegnelsen «esmarkium» muligens brukes. Rosendahl holder det for sannsynlig at Moelv-sparagmitten svarer til sandstein-skiferformasjonen mellom de to tillitter i Finnmark, noe også enkelte andre norske geologer (bl.a. Skjeseth) er tilbøyelig til å anta.

Også forholdene i enkelte andre områder med fossil-tomme lagrekker direkte under fossil-førende kambrium ble omtalt, særlig Grønland.

På møtet i N.G.F. i november mente de fleste av dem som uttalte seg at det naturlige var å bruke «eokambrium» om bare den øvre del av de lagrekker det her gjelder, lagrekken fra de eldste glacial-avsetninger og til det fossilførende underkambrium. For Finnmark er grensen klar i og med at man der har en tydelig diskordans som skiller mellom før-tillittiske og yngre dannelser, for det sydnorske område er forholdene mer uklare som ovenfor antydet.

B. Asklund:

Vid en historisk återblick på problemet «eokambrium» konstaterar man den olika tradition, som utvecklat sig. I Norge hade man følјt Kjerulfs indelning och den nomenklatur, som Brögger sannolikt i anslutning till de vid Pariskongressen år 1900 diskuterade nomenklaturfrågorna givit. I Sverige hade Törnebohm och Högbom däremot följt den internationella terminologien, som grundlagts av särskilt Walcott, och därmed hänfördes «seve»-avlagringarna till prekambrium och den algonkiska eran. Vid återupptagandet av de stratigrafiska studierna av de klastiska seveavlagringarna hade talaren följt den svenska traditionen och sålunda betecknat kvartsit-skifferformationen, inrymmande kvartssandstenen och Ekreskiffrarna, tilliterna och de «röda» och «grå» sparagmitformationerna såsom algonkiska. Men samtidigt hadde talaren betecknat kvartsitskifferformationen såsom «eokambrium i inskränkt bemärkelse». Anledningen därtill var att talaren funnit det otvetydigt, att kvartsit-skifferformationen tillhör de inledande kaledoniska geosynklinalsedimenten och därmed måste tolkas som i stor utsträckning marina avlagringar, som följa geosynklinalens NO—SV-liga orientering. De skilja därmed ur allmängeologiska synpunkter grundväsentligt från de närmast underliggande sparagmiterna, den röda sparagmitavdelningen, vars sediment måste uppfattas som till största delen terrestriska, med bl.a. en mängd konglomerat, vilka i största utsträckning torde vara flodplansbildningar. Sparagmitbäckenens orientering i NV—SO är dessutom mycket olikartad med kvartsit-skifferformationens (se Asklund, Stratigrafien inom södra Lapplands kvartsit-sparagmitbildningar, SGU, Ser. C 387, 1935, pp. 45—54.

För kvartssandstenens avskiljande från kambrium hade Thorolf Vogts resultat från Mjösen varit avgörande; konstaterandet av en

vitt utbredd diskonformitet. I Jämtland hade talaren delvis funnit sedimentationsavbrottet ännu mera utpräglat, ibland med karaktären av en vinkeldiskordans. Vogts slopande av termen «eokambrium» fann talaren mycket logiskt ur de internationella synpunkter, som bruka tillämpas vid särskiljandet av geologiska system, men å andra sidan skulle ju kvartsit-skifferformationernas sammanförande med «sparagmitium» innebära vissa inkonsekvenser ur lithologisk synpunkt och som ovan anförts även ur geologiska. De svenska kvartsit-skifferkomplexen innehöllo ju inga verkliga sparagmiter i de trakter talaren utforskat.

Vid en omprövning av hela det stratigrafiska problemet hade talaren kommit till den uppfattningen, att undre gränsen för «eokambrium» bör läggas vid den undre tillitens botten (se B. Asklund och Nils Marklund, Aktuella skandinaviska fjällproblem, G.F.F. 76, 1954, sid. 125). Efter det nya fyndet av en övre tillithorisont i Jämtland, liggande över en mäktig konglomeratisk kvartssandstensavdelning, hade talaren ännu mera bestyrkts i denna uppfattning, då ju därmed tilliterna visa ett otvetydigt sammanhang med de äldre delarna av kvartsit-skifferformationen. Fördelen med att lägga gränsen vid den undre tillitens botten är icke minst att man därmed får en övre kronologiskt skarpt markerad gränsdragning mot underlaget. Det kunde ju nämligen knappast råda något tvivel om att de bägge tillithorisonter, som äro kända från Varangerområdet, numera Jämtland och Østgrönland äro isokroma bildningar. Den undre tilliten har ju delvis ännu mera omfattande utbredning (Spetsbergen m.m.).

Frågan uppstår om man bör behålla namnet «eokambrium». I anförd omfattning och med angränsning från Vogts «sparagmitium» synes det av traditionella skäl kunna ifrågasättas. I större konsekvens med internationell terminologi vore det sannolikt lyckligare att införa ett nytt namn. Kulling har i det avseendet givit ett gott uppslag med beteckningen «Varangeristiden» för eokambriums istid. I Per Holmsens föredrag i dag hörde vi talas om «Varangertiden». Enligt talarens mening skulle benämningen «Varangium» stöta på språkliga svårigheter för att bli internationellt upptaget. Talaren hade därför tänkt sig en benämning «Varegium». Den för i minnet platsen för Reusch's storartade upptäckt av en prekambrisk istidsbildning å Varjag-Njargga, det lappska namnet på Varangerhalvön, men minner samtidigt om det åldriga grekisk-ryska folknamnet å vikingatidens nordbor, vare sig svenskar eller norrmän, *varjager* eller *vareger*. «Varegium» skulle därmed även ur etymologiska synpunkter utgöra en motsvarighet till systemnamnen kambrium, ordovicium och silur, som givits från åldriga folknamn. Dess avgränsning nedåt erbjuder inga större svårigheter och beträffande dess avgränsning uppåt torde ju alltjämt Walcotts synpunkter böra vara de ledande.

Minutes from the Conference on Water in Soils.

Seksjonen ble ledet av dr. I. Th. Rosenqvist.

Det ble diskutert vannets bevegelse under små trykkgradienter i finkornige jordarter med lav permeabilitet, videre vannets bevegelse i finkornige jordarter under telefrysning og til slutt vannets bevegelse i finkornige jordarter under temperaturgradienter.

Innledere for de tre temaer var:

Dr. Rosenqvist,
Professor Beskow og
Agr. lic. Erik Saare.

Diskusjonsinnleggene fra flere av deltakerne tjente til å belyse problemkomplekset, som særlig dreiet seg om den innbyrdes betydning av strømningsfenomener, der D'Arcys lov er gyldig, og diffusjonsfenomener der de termodynamiske potensialgradienter er avgjørende. Særlig ved islinsedannelse under telefrysning og ved vannets bevegelse i jordarter med variabel temperatur syntes diffusjonsfenomenene å være av så stor betydning at de ikke kan settes ut av betraktning ved eksakt behandling av problemene. Hvorvidt diffusjonen også spiller en rolle når permeabiliteten blir meget liten og trykkgradientene ligger under en viss størrelse, var det derimot vanskelig å avgjøre på grunnlag av de innlegg som kom. Det mangler åpenbart eksakte målinger. Konklusjonen på gruppemøtet ble at det synes her å foreligge et stort og temmelig ubearbeidet forskningsfelt.

Trykt august, 1956.

NORSK GEOLOGISK TIDSSKRIFT 36

GEOLOGY OF THE STORKOLLEN—BLANKENBERG AREA, KRAGERØ, NORWAY

BY

JOHN C. GREEN

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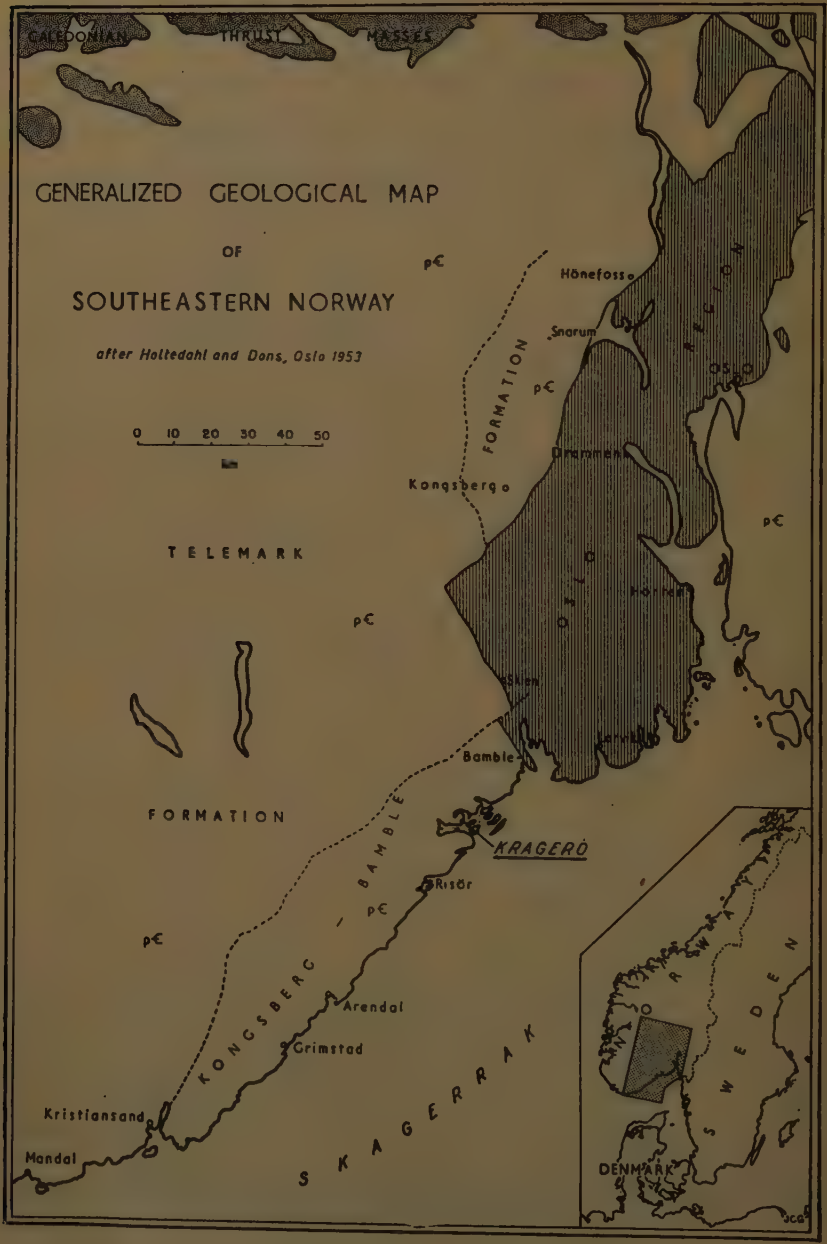
Abstract. The high-grade quartzites and schists of the pre-Cambrian Kongsberg-Bamle formation in the Storkollen-Blankenberg area, Kragerø, enclose small gabbroic stocks which were centripetally altered to amphibolite during the Sveco-fennide (?) metamorphism. Associated with the gabbros and probably derived from them are dikes and irregular bodies of granulose albitite containing varying amounts of other minerals, notable among which are quartz, microcline, rutile, and tourmaline. Certain areas of the large rutile-albitite body of Lindvikskollen (kragerøite) were found to contain corundum; this is a new locality for corundum in Norway. Euhedral tourmaline crystals in an albitite-amphibolite transition zone were found to be an Mg-rich variety;


CALEDONIAN THRUST MASSES
GENERALIZED GEOLOGICAL MAP
OF
SOUTHEASTERN NORWAY
after Holtedahl and Dons, Oslo 1953
0 10 20 30 40 50
km
pЄ
Hönefoss
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Arendal
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Kristiansand
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this is also a new locality. It is concluded that most if not all of the albitites were formed metasomatically from preexisting amphibolite.

Late in the orogeny, large, rare-earth bearing pegmatites were intruded in a highly liquid state, and cooled slowly with several stages of mineralization, including a partial replacement of microcline by cleavelandite.

Finally, after shearing stresses had locally faulted and brecciated the rocks, iron oxide mineralization took place along a small east-west fissure.

Introduction.

The Pre-Cambrian rocks of the south Norwegian coast from Langesundsfjord to Kristiansand are known as the Kongsberg-Bamle formation, which is separated from the main southeastern Norwegian Pre-Cambrian area by a major breccia zone (A. BUGGE, 16[1]). Near the northern end of this strip lies the town of Kragerø, (see index map, p. 90), protected from the storms of the Skagerrak by a multitude of islands, or skjærgård. Just west of the town lies a unique area whose amphibolites contain many large pegmatites and albitite bodies. A geological study of this area was carried out during my stay in Norway under a United States Government Fulbright Scholarship for the year 1953-54.

Seven weeks of field work were undertaken in the fall of 1953 and one week in May, 1954, mapping, making detailed field observations, and collecting specimens. The winter and spring were spent at the Geological Museum of the University of Oslo, whose facilities were kindly made available to me by Prof. Dr. TOM. F. W. BARTH, the Director. Detailed study of the collected material was carried out with the aid of refractive index determinations, thin sections, Universal stage methods, X-ray mineral determinations, chemical tests, and heavy-liquid and magnetic separation methods. The tables by TRØGER (30) were used for most of the refractive index work, but use was also made of LARSEN and BERMAN (23) and TSUBOI (31). A geological map was made to the scale of 1/5000, based on a topographic map drawn by myself from aerial photos and aneroid barometer observations. The mapped area is about 2 km^2 in area, its eastern edge passing through the top of the hill Storkollen, the northern edge lying in the Kalstad—Leirvik—Ånevik valley, and having the Kilsfjord as the southern and western limit. The less accessible portion west of the Kammerfoss River was only roughly investigated (two days of field work), the bulk of detailed study being concentrated in the area between Storkollen and the river.

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[1] Numbers refer to list of references, p. 138.

W. C. Brøgger, Olaf Andersen, and Harald Bjørlykke have done most of the previous work in this area. Brøgger led many excursions to Kragerø from the University of Oslo in the 1890's and the first quarter of this century, and studied his collected material in great detail. Within the area concerned in the present report, his main interest lay in the rare pegmatite minerals (12, 13) and the kragerøite and other leucocratic dikes (15). He also investigated the nodular granites and related rocks of the surrounding Bamle complex (14), but scarcely touched upon the gneisses in the immediate vicinity of this report.

V. M. Goldschmidt did considerable spectroanalytical work on the Kragerø pegmatite minerals (19).

Olaf Andersen studied in particular the feldspars of the large pegmatites (1, 2, 3), mapped the area with T. F. W. Barth and also collected specimens in the albitites and surrounding amphibolites. I am greatly indebted to the Norsk Geologisk Undersøkelse for permission to use the thin sections and hand specimens of Andersen's collection.

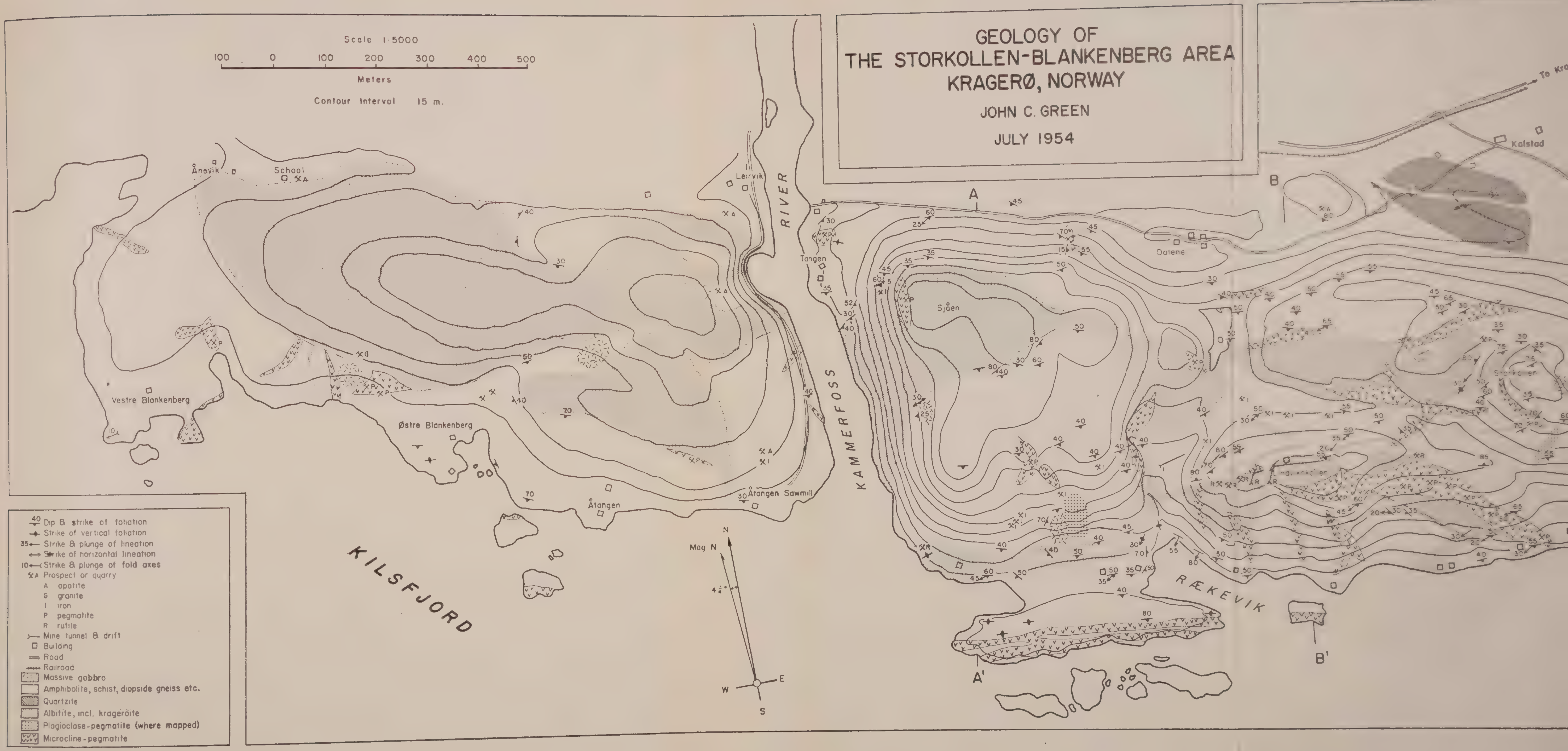
Harald Bjørlykke also concerned himself with the large pegmatites, and wrote several papers on their mineralogy, deducing a system of pegmatite classification based partly on the Kragerø mineral associations (6, 7, 8, 9, 10, 11).

Arne Bugge mapped the regional geology around Kragerø in 19 , but has not completed or published his map. His large work published in 1936 (17) covers the whole Kongsberg-Bamle formation.

A more complete investigation of this formation was carried out by Jens Bugge, beginning in 1937, and concentrating in the Arendal area to the southwest. His results were published in 1943 (18).

In 1939 Brit Hofseth mapped and studied the granite of the Levang Peninsula, immediately south of the present area, and in 1940 the dolomite occurrences in the Kragerø region. Her work was published in 1941 (21).

A. F. Frederickson did field work in the Kragerø Peninsula in 1951—52, but his results have not as yet been published.



GEOLOGY OF
THE STORKOLLEN-BLANKENBERG AREA
KRAGERØ, NORWAY

JOHN C. GREEN

JULY 1954

Geological Environment.

The Bamle formation at Kragerø is composed of a series of generally NE-striking interbedded banded gneisses quartzites, mica schists, and amphibolites, including granitic bodies (Levang granite), olivine-gabbros (Valberg Peninsula), and small to large albitite and pegmatite bodies, usually lensoid or dike-like in form. Post-metamorphic diabase dikes cut the rocks in a few places (Risø).

Many different types of local mineralization occur. Scapolite is a very common mineral in the Kragerø area, occurring as an alteration of plagioclase in the gabbros and as fissure-fillings, often with hornblende in large crystals, in amphibolites and gabbros. Of economic importance have been red apatite (found with hornblende, scapolite, rutile, calcite, and enstatite, in certain mineralized zones in crystals up to a meter long and 20 cm in diameter) and white dolomite, in hydrothermal deposits up to several meters wide occurring along fault zones and other fractures. Associated with the dolomite in two quarries visited by the author (near Aasen, Kammerfoss, just north of the map area) were found blue-green calcite, diopside, tremolite, talc, and pyrrhotite. Both apatite and dolomite have been intermittently mined for many years. A fissure containing iron oxides extends east-west across the map area, and has been worked at several places.

Structure.

The rocks in the Storkollen-Lindvikskollen-Sjåen area are characterized by a general E-W strike and a southerly dip ranging, with a few exceptions, from 35 to 60 degrees (see structure sections, Fig. 1, and geologic map). A lineation in the plane of schistosity is often present, plunging SW or WSW in nearly all observed instances, indicating conformity to a general regional deformation. The type of lineation ranges from a preferred orientation of tourmaline needles in albitite dikes through drawn-out clots of minerals in amphibolites to minor fold axes and cataclastic stretching features in the schists.

There are several local disruptions of this regional trend, however. The northwest flank of the hill Storkollen contains a gentle syncline plunging to the southeast, and the rocks forming the north flank of

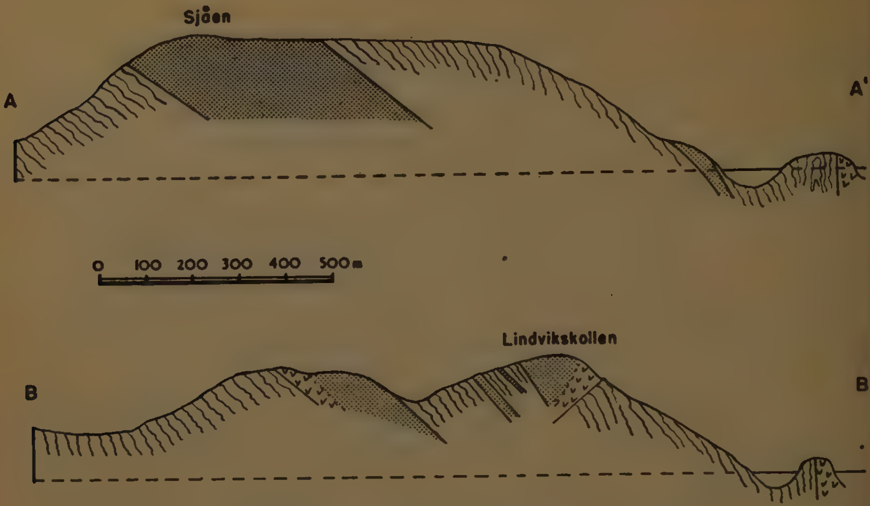


Fig. 1. Structure sections AA′, BB′ across map area.

the hill Sjåen, from the pond at Dalene almost to Tangen, strike NW to WNW. At the head of the cove Rækevik a considerable shearing deformation has taken place; the farm just to the west lies in the middle of a smooth anticline plunging steeply SE, and at the east-facing cliff 200 to 400 meters north of this, the rocks are vertical, close to normally oriented rocks only a few meters west of the cliff top. In the valley below the cliff, the rocks (here more schistose) show tight, small wrinkles, low-grade alteration, and other signs of late-metamorphic shearing movements. On the two-ended peninsula to the south the strike is uniformly E-W, but the dip rapidly becomes steep to vertical southward across the peninsula. Vertical, isoclinal folds occur towards the western end.

About 200 meters west of the top of Storkollen there seems to be another roughly N-S shear zone, separating two parts of an albitite body by a narrow band of schist and gneiss. Here also the schistosity is vertical with an anomalous strike, and a narrow valley has been cut along the shear zone. All along the northern edge of the mapped area, along the lower flank of the hill, the schists are considerably wrinkled into small-amplitude folds. The amphibolites east and north of the Tangen pegmatite are also highly and often sharply folded. At

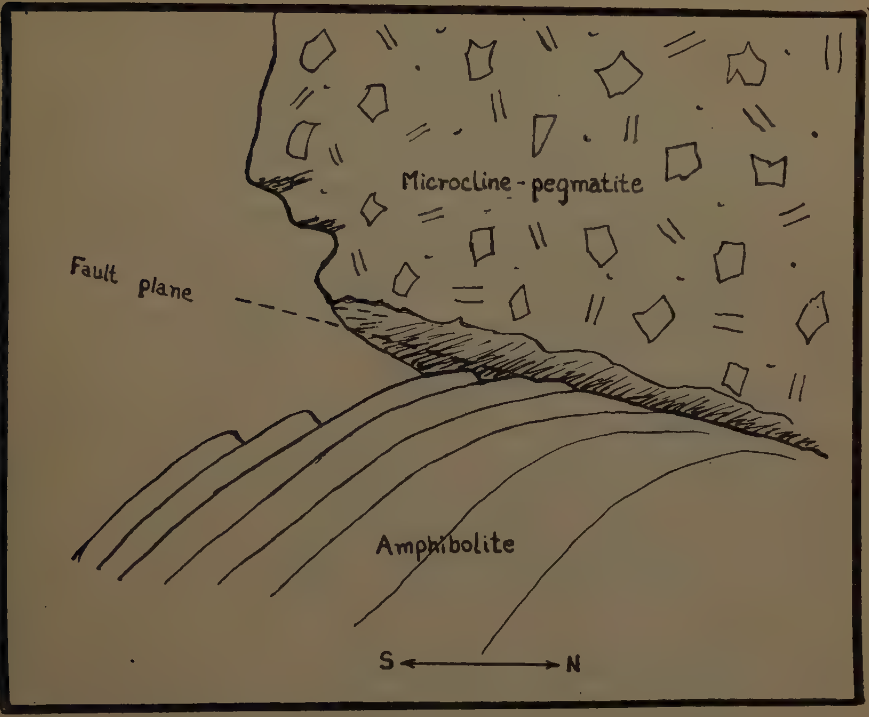


Fig. 2. Faulted pegmatite-amphibolite contact, Kalstadgangen quarry.

the mouth of the Kammerfoss River a narrow strip of schist between two conformable albitite bodies has acquired a vertical orientation.

Several post-metamorphic faults were observed, but their displacement could not be determined. The south contact of the eastern end of the Kalstad pegmatite lies in a fault plane dipping about 10° NE to N. It is especially well exposed at the quarry loading bins, where the underlying amphibolite has been dragged northward along the fault. See Fig. 2.

Two faults were observed in and bordering the main kragerøite body on Lindvikskollen; each of the two main rutile stopes follows one of these faults for some distance. In the smaller, western stope, the fault plane forms the north contact of the kragerøite against amphibolite, and has been laid bare by removal of the rutile ore on the south side. Here the fault plane strikes about E-W with a steep, irregular dip to the south. The texture of the slickensides indicates that at least in one movement, the south (kragerøite) wall moved down and to the west relative to the north wall. The larger eastern rutile mine follows the second fault for about twenty meters at its entrance tunnel, before turning east into the main stope. This fault strikes N9° E and is approximately vertical. These faults are characterized by the formation of a zone of biotite rock several centimeters thick; under the microscope the biotite is seen to bend around small lenses of muscovite, quartz, albite, and calcite.

Topographic evidence suggesting two or three N- to NE-striking faults can be seen towards the east end of Sjåen, but geologic evidence is difficult to find. From the relative positions of albitite, amphibolite, and an iron fissure on each side of the Kammerfoss River, it seems reasonable to infer a N-S fault along the river. A steeply dipping, arcuate fault is evident on the hill west of the river, where a narrow band of amphibolitic schist in a small valley separates a small albitite body from the major outcrop. The albitite lies conformably on the south-dipping schist of the southern block, which evidently moved upward relative to the north block.

An interesting phenomenon was observed about 500 meters east of the top of Storkollen, off the map area; a small pegmatite there has been partly brecciated, and the resulting compact, angular breccia has a matrix composed largely of calcite.

An albitite along the new road just north of Leirvik has also been strongly crushed.

Petrography.

The country rocks for the albitites and pegmatites in the mapped area would seem to represent a series of sediments and lava flows into which olivine-gabbro magmas have been intruded. Many varieties of similar, related rocks of this complex from elsewhere in the Kragerø area have been described by W. C. Brøgger (14, 15), Arne Bugge (17), and Jens Bugge (18). After the intrusion of the gabbros, the whole complex was subjected to the P, T conditions of the amphibolite facies. This has been referred to the formation of the ancient Sveco-fennide mountain range of southern Scandinavia by A. Bugge (1941) and Th. Vogt (1938). Age determinations on uraninite (without isotope determination of the lead) from pegmatites near Arendal gave about 1050 million years; the zircon age from pegmatite near Tvedestrand (also in the Bamle formation) gave 720 million years.

The cores of the largest gabbro bodies, however, escaped metamorphism and still retain their original ophitic texture and mineralogy. The preservation of the original character of these gabbro cores must be referrred to the dense, impermeable nature of the rock. As the P, T conditions within the solidified gabbros and outside them must have been roughly the same, it seems in this case that water, diffusing in from the surrounding sediments, was the active agent of metamorphism.

Gabbros. BRØGGER (15) has thoroughly described the largest gabbro bodies of the Kragerø area. Macroscopically the typical gabbro («hyperite») is a heavy, dark brownish-violet, medium-grained rock composed chiefly of large individuals of clinopyroxene enclosing smaller laths of labradorite, with lesser amounts of olivine, biotite, orthopyroxene, black ores, apatite, etc. Perhaps the most remarkable features of these rocks are the corona structures or reaction rims often developed around olivine and ore minerals when in contact with plagioclase (in the zones undergoing incipient metamorphism). Between olivine and plagioclase, hypersthene forms nearest the olivine, with hornblende including tiny spinels as an outer rim; biotite, hornblende, and garnet form the corona around the ore grains. Furthermore, parts of most of the gabbro bodies are often altered to scapolite-hornblende rock.

In the present area, I have found five separate ophitic cores of gabbro bodies, and it is quite possible that others have been overlooked, for the core areas are rather small. The westernmost one lies about halfway between Eastern (Östre) Blankenberg and Western (Vestre) Blankenberg. It contains a scapolite-hornblende facies. About 300 to 400 meters ENE of Östre Blankenberg another was found also containing scapolite. Its plagioclase, where not scapolitized, is a fresh, zoned labradorite. Another relict gabbro lies at the top of the cliff about 200 meters south of the Sjåen pegmatite. Olivine was seen in neither this nor the second-named outcrop, but very likely was originally present. The plagioclase at Sjåen is zoned and fresh, with cores An 72 and rims An 48. This gabbro differs from the great majority microscopically examined by Brøgger or myself in that it has reaction rims between the mesostatic clinopyroxene and the plagioclase. The corona consists of a pleochroic hornblende, oriented with its c-axis parallel to that of the pyroxene, and with minute quartz (?) grains strung along the boundary between the hornblende and pyroxene.

The next gabbro body was found to form a cliff about 200 meters northwest of the farm at Rækevik. A concentric foliation is particularly well developed around the borders of this roundish body; biotite schist lies at the most 50 meters from the ophitic, olivine-bearing core, which closely resembles the «hyperite» from Valberg described by Brøgger. The plagioclase has cores of An 68, and rims An 37. A fifth gabbro crops out at the top of the cliff on the east side of the top of Storkollen. It resembles in hand specimen the hyperite from Valberg, but has not been examined microscopically.

Amphibolites in the Storkollen—Lindvikskollen—Sjåen area crop out for the most part on the top and flanks of Storkollen, the south side of Lindvikskollen, and the large southern shoulder of Sjåen. Typically they contain from 50 % to 60 % of mafic minerals, preponderantly amphibole, and 40 % to 50 % of plagioclase, usually an andesine (An 35-40). Other common minerals are biotite, opaque ore, garnet, epidote, sericite, chlorite, calcite, and apatite. Less common are quartz, rutile, scapolite, prehnite, (as lenses in biotite), sphene, serpentine, and zircon.

The amphibolites have a gneissic to schistose structure formed by the parallel planar arrangement of amphibole and biotite, and very commonly a lineation formed by elongated clots of mafic or felsic minerals or by a parallelism of the hornblende prisms.

Several thin sections of macroscopically «typical» amphibolite seem, by their anomalous mineralogy, to be highly altered gabbros. They are scattered almost all over the map area. Some of these contain relict scraps of ortho- and clinopyroxene, being altered to amphibole; one contains plagioclase with a composition An 66; another has zoned plagioclase with cores An 60 and rims An 40; another is composed entirely of a ferrous amphibole (90 %) and large, inclusion-filled garnets; another contains only about 2 % plagioclase, which shows the typical complicated igneous twinning. Most of these rocks incorporate a number of these anomalous features. In fact, all gradations can be seen between the ophitic, olivine-bearing gabbro and the schistose, completely metamorphosed amphibolite, and it is clear that a very large portion of the present amphibolite originated as stock-like gabbroic intrusions.

All the amphibolite, however, cannot be assigned to gabbros directly. Sills, lava flows, and sediments have contributed their share. To cite an example, a persistent bed of amphibolite about four meters thick lies in an impure quartzite between the farms Kalstad and Dalene in the northeast corner of the map area. Considering the massiveness of the surrounding quartzite, it is reasonable to assume that this amphibolite was once a basaltic lava flow, and not an intrusive.

Garnet-rich horizons, traceable for considerable distances along the strike, are a common feature in the amphibolites. The garnets are up to 5 or 6 cm in diameter, and comprise up to 30 % of the rock. They are a common red almandine, crowded with inclusions of the other rock constituents. As they grew, they seem to have replaced plagioclase more easily than amphibole. No particular orientation of the inclusions was observed.

Scapolite-hornblende rocks were found both as an obvious alteration facies of the gabbro and as perhaps independent, locally-altered amphibolite. An occurrence of the latter type crops out near the top of the hill north of the Rækevik house, where a small quarry has been worked on an iron-bearing fissure. Considerable calcite has been introduced with the iron ores, and this may have been linked with the scapolitization of the surrounding plagioclase.

The amphiboles of the amphibolites are strongly pleochroic hornblendes and actinolitic hornblendes as a rule, with a high Fe/Mg ratio, according to refractive index determinations. An average of twelve amphibolite amphibole determinations, using Trøger's tables, gave an Fe/Mg ratio of 62/38. Weakly pleochroic gedrite is found in a few of the more schistose zones (north flank of Sjåen), evidently representing an aluminous bed in original mafic sediments. In one such specimen the gedrite has an Fe/Mg ratio of about 50/50 (mol.).

Schists crop out along the north flanks of Storkollen, Sjåen, and Lindvikskollen, at the neck of the peninsula at Rækevik, west along the shore to Blankenberg, and at other places over the map area. They show all variation between amphibolites and quartz-mica schists, with such intermediate types as gedrite-biotite-andesine schist (N. Sjåen), biotite-hornblende-oligoclase-scapolite schist (W. Storkollen), and biotite-tourmaline-quartz-oligoclase schist (N. Sjåen). A schistose mica-quartzite from the northern base of Storkollen contains 78 % quartz, completely recrystallized, 22 % white mica, and traces of apatite and zircon. Brøgger has described several typical varieties of schist from the Kragerø region (14, 15), and for more thorough descriptions the reader is referred to these papers.

The above-mentioned schist from West Storkollen has a striking porphyroblastic structure. Roundish oligoclase crystals (An 19) are growing in a highly schistose matrix of biotite, hornblende, scapolite, apatite, and magnetite, partly replacing the other minerals and partly shoving them aside. The rock has a knotty appearance, and the porphyroblasts, which have attained a diameter of about 5 mm, contain countless oriented inclusions of the earlier minerals. Particularly interesting in this rock is the apparent compatibility of the scapolite crystals (which amount to 5 % of the rock) with the plagioclase.

A peculiar schist occurs in the shear zone in the valley north of Rækevik, at the old iron mine. It is fine-grained, has a shiny, grayish-green appearance, and consists of pale chlorite, 45 %; oligoclase (An 16), including small amounts of sericite and calcite, 40 %; magnetite, 5 %; and apatite, 1 %.

Quartzites, some of them very pure, crop out in the Kragerø area, and are quarried at several localities in the skjærgård (Berø, Blanktjern, etc.). In the present map area quartzites are limited to the northeast corner near Kalstad, and they are for the most part rather impure. One specimen from this locality contained 70 % quartz, 5 % microcline, 14 % plagioclase (An 63; the grains have been mostly altered to white mica, but the edges are often fresh), 9 % biotite, including interfoliar lenses of prehnite, 2 % of tiny sillimanite rods in zones parallel to the bedding, a few muscovite and apatite grains, and traces of zircon and rutile. The sillimanite shows a strong linear orientation plunging WSW, parallel to the regional lineation. A conformable «bed», about 3 mm wide, of quartz and fresh microcline runs through the specimen, having considerably larger grains than the groundmass. The original sedimentary compositional banding is very well preserved although the rock is thoroughly recrystallized.

The assemblage quartz-sillimanite-microcline-muscovite-plagioclase is of interest, as only four of these minerals would ordinarily be

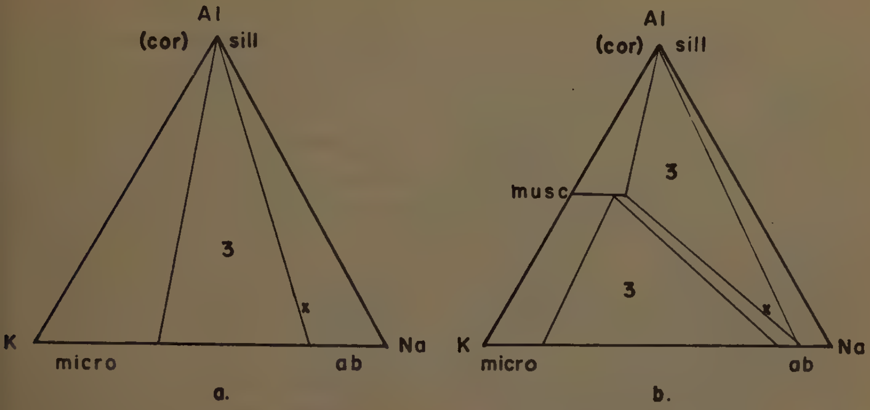


Fig. 3. K-Al-Na diagrams of aluminous rocks with excess (sillimanite) or deficient (corundum) silica; a: high amphibolite facies; b: medium grade.

expected at a random P, T, chemical potential H_2O. The muscovite is seen to be partly pseudomorphous after biotite; some biotite grains suddenly lose their color at an irregular but sharp line, but the crystal continues as a white mica. In other cases, muscovite is obviously an alteration product of plagioclase. A third type of occurrence is in intimate association with microcline, but both seem texturally to be equally stable. In one spot only was microcline seen next to sillimanite. Biotite is in a small area altered to chlorite.

The best explanation seems to be that metamorphic conditions exceeded the stability field of muscovite, giving sillimanite and microcline in stable association, but later introduction of water (possibly at a lower T) allowed retrograde action to re-form muscovite from the other minerals (see Figure 3a, b).

As most observers have noted, these various schists and quartzites undoubtedly represent an ancient sedimentary complex.

Albitites. The great number of bodies of fine to medium-grained leucocratic rocks which crop out in the mapped area present a small problem in nomenclature, as no term in use today adequately applies to all these undoubtedly related rocks. They are characterized by a sodic plagioclase (An 0 to 12) as the major constituent, with highly varying amounts of quartz and microcline, plus accessory minerals such as biotite, rutile, hornblende, tourmaline, sphene, and zircon. These rocks vary in many respects, but it is evident that most of them, at least, have had a common origin, and it has been expedient to find a single, general, descriptive term which could be applied to all of them as a group. Brøgger (15) has used the term «albitite», with apt mineral prefixes, and this seems to be the least confusing and most convenient name, although these rocks sometimes contain up to 50 % quartz or 30 % microcline, or an oligoclase-albite instead of an albite.

These albitites attain their greatest development in the area from Storkollen west across the Kammerfoss River to Ånevik. A few samples from this area have been studied by Brøgger (15), who also described similar rocks from the islands east of Kragerø and from several other localities in the Kongsberg-Bamle formation even as far away as Snarum, 130 kilometers to the north.

The albitites occur as dike-like bodies from a few centimeters up to 400 meters in width. Two major bodies are present, the kragerøite of Lindvikskollen, approximately 350 × 60 meters, and the great quartz-albitite mass which extends WNW from the west flank of Storkollen for 2.6 kilometers, with an outcrop width ranging from less than 40 up to 400 meters. Many smaller dikes and smears of albitite are found, most of which have conformable but gradational contacts against the surrounding amphibolite.

W. C. Brøgger studied and originally named the large kragerøite body which crops out on Lindvikskollen (15, pp. 181—197). It is a massive, granoblastic albite-rock with a grain size of about 1 to 3 mm, and having a gray to pink to white color when fresh. Its plagioclase is an albite, An 3-4, often slightly sericitized, with twins after the albite law. An alkali determination by Miss Erna Christensen in the laboratory of the Norwegian Geological Survey (Norges Geologiske Undersøkelse), 1954, gave Na_2O: 10.56 %, K_2O: 0.52 %, giving a three-component composition of Ab 94, An 3, Or 3. Aside from albite, which makes up the great bulk of the rock, the following minerals occur in at least accesoric amounts: rutile, biotite, tourmaline, apatite, iron ores (mostly pyrite), sphene, actinolite, chlorite, zircon, and calcite. The rutile is the most characteristic accessory in this body; Brøgger's name «kragerøite» refers to albitite with a considerable amount of rutile.

Five minerals other than albite attain fairly large volume percentages in various parts of this body. Quartz makes up from O to 25 % of the rock, and according to BRØGGER (15, p. 196) is most highly concentracted near the northern side of the occurrence. (During the course of my recent investigations, no kragerøite was observed with more than about 10 % quartz). This mineral occurs in rounded, usually interstitial grains with undulatory extinction.

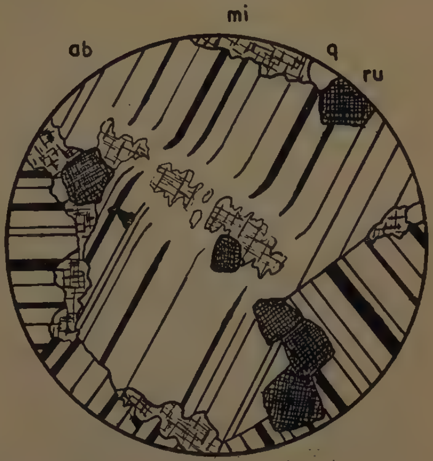


Fig. 4. Krg I 25. Kragerøite, Lindvikskollen. Ab, albite; ru, rutile; mi, microcline; q, quartz. x160.

Perfectly fresh microcline is usually present, and comprises up to 10 % of some specimens. Thin sections show the microcline to be, at least in part, replacing albite. It occurs along the grain boundaries of the albite, and in patches within it, with ragged contacts and twinning often parallel to the albite twinning. Some of this is probably due to exsolution, although a regular, subparallel antiperthite texture was nowhere seen. One large albite grain showed a stressed zone where its twin lamellae are bent; the twinning disappears toward the center of the zone, where an irregular patch of microcline is found (see Figure 4).

Small grains of pyrite comprise up to about 10 % of certain zones of the kragerøite body, especially at the east end of the large rutile mine.

A black tourmaline, in small clusters of grains ranging in size from $^1/_4$ to 3 mm, is found in the area of the smaller mine to comprise up to at least 16 % of the rock. It is pleochroic, O = brown or bluish-green, E = reddish or smoky, and its calculated composition from BRØGGER is here included in Table I, p. 00. This tourmaline has a somewhat higher Mg/Fe ratio than a typical schorl.

One of Brøgger's thin sections (Krg I 18) of a quartz-rich kragerøite specimen contains, besides microcline and a few grains of pale biotite, apatite, and ore, several small, corroded crystals of another

Table I

	A	B
SiO_2	35.23	36.67
TiO_2	0.38	0.97
Al_2O_3	34.31	31.70
Fe_2O_3 }	7.82	3.40
FeO }		0.57
MnO	0.12	0.00
MgO	5.13	9.91
CaO	0.13	0.95
Na_2O	2.19	0.60?
K_2O	0.75	0.22?

Partial chemical analyses of tourmalines from Lindvikskollen. A, tourmaline from tourmaline-kragerøite, Mine 3, Rødland analyst, 1923 (Brøgger, 15, p. 238). B, tourmaline from albitite-amphibolite transition, entrance to Lindvikskollen pegmatite quarry, E. Christensen analyst 1954.

variety of tourmaline. It is strongly pleochroic, O = blue, E = pale green, and is evidently an alkali-rich variety. Alkali tourmaline has been described so far from only one other Norwegian locality, a cleavelandite-quartz pegmatite at Åg in Meløy, Nordland (Oftedal, 26). The Åg tourmaline is zoned and contains considerable Na and Mn, and some Li, and is associated with spodumene. The newly described Kragerø variety does not show zoning, and has been found in too small amounts for a refractive index or spectrographic determination. Its occurrence in the albitite, however, suggests a high Na content.

Rutile attains the highest concentration of any mineral in the kragerøite, with the exception of albite. Although distributed throughout the body in amounts of at least 0.5 %, it is found in the easternmost part to form black streaks and concentrations which in the richest zones almost completely exclude all other minerals. These rutile «schlieren» are oriented parallel to the north wall of the body, and thus dip steeply south. The surrounding kragerøite contains roughly 5 to 8 % rutile. This deposit has been mined sporadically since 1901, but the ore is apparently at present prices and quality not economically mineable in competition with ilmenite from the large mine in Sogndal, southwestern Norway. There is a string of pits and quarries near the northern contact, and two large underground workings exist towards the top of the hill which connect with older surface holes. A single-span aerial bucket system took the ore down to a loading pier at sea level.

The rutile occurs as generally equidimensional grains, anhedral to euhedral, 0.5 to 2 mm in size; black in hand specimen but of a deep red color, pleochroic, in thin sections. The grains commonly occur grouped in small streaks, giving a weak gneissic structure to the otherwise massive rock.

Brøgger gives a figure of 6.32 % Fe_2O_3 for the iron content in the average rutile. A partial analysis by E. Christensen (1954) of rutile from a small pegmatitic zone in the kragerøite body gave the following results: 0.18 % Cr_2O_3, 1.08 % SiO_2, 1.05 % Fe_2O_3, or a considerably purer rutile than that of the finer-grained rock.

One specimen of typical gray, medium-grained kragerøite from the large mine contains a number of radial clusters of anthophyllite about 3 mm in diameter. The anthophyllite occurs as very fine fibers, with a silky sheen and a white to pale green color. Its refractive indices show it to be a pure Mg-amphibole. The clusters are often centered around small pyrite grains. This is as far as I know the first observation of this mineral in the kragerøite.

Small pegmatitic areas in the kragerøite body are made up of the same minerals as the surrounding kragerøite; thus, large grains of albite (slightly more calcic than usual, An 5—6), rutile, quartz, biotite, pyrite, apatite, and sphene. Microcline and tourmaline have not been identified in such pegmatites, but are to be expected. The pyrite occurs closely associated with biotite and quartz. The pegmatite can have rather sharp contacts against the normal albitite. Some of the pegmatitic albite has about 2 % of microcline in thin, antiperthitic lamellae. An alkali determination of albite from this kragerøite pegmatite (Christensen, 1954) gave 10.86 % Na_2O, 1.28 % K_2O, or Ab 95.5, An 4.4, Or 10.1.

A large volume of the rock lying between the two large mines is of a peculiar veined or patchy appearance (see Plate Ia). White veins seem to penetrate and interweave a grayish groundmass, giving the impression of a mineralized and then recrystallized breccia. Thin sections prove the opposite to be the case, however. The white «veins» are actually typical, medium-grained kragerøite (slightly sericitized albite, An 4, with minor rutile and biotite), while the darker patches are a finer-grained, fresher rock with decussate texture, consisting of fresh albite, biotite (15 %), tourmaline (4 %), rutile (3 %), and muscovite (not paragonite; 12 %), the latter usually surrounding tiny grains of corundum, which amounts to about 1 % of the rock (see Plate IIb). The corundum has very high relief, n $\approx$ 1.765, and is uniaxial negative. This is a new locality for corundum in Norway, and a rather unique mode of occurrence.

The appearance of corundum and muscovite in this rock presents an interesting problem. As the corundum is almost always surrounded by muscovite with the relations of a reaction rim, one is led to the conclusion that the muscovite formed as a synantectic mineral from the earlier association corundum-potassic albite. This would be completely analogous to the situation described above in an aluminous quartzite, where the introduction of water, probably at a lower temperature, produced the muscovite-bearing assemblage. On Figures 3a, b, the corundum-albitite would plot at x. The striking difference is the deficiency of SiO_2 necessary to produce the corundum, in a rock which otherwise has free quartz and never has been found to contain an aluminum silicate. This problem will be considered more fully in the discussion on the genesis of the albitites (p. 129).

The main body of kragerøite extends from the top of Lindvikskollen westward until it reaches a pegmatite striking N on the southwest corner of the hill. Approximately at this pegmatite the kragerøite proper ends, but it reappears as a narrow, conformable dike or sill above the houses west of Rækevik, and from there continues west into the fjord. Towards its western terminus this body divides into at least three branches, the northwesternmost showing the greatest resemblance to the kragerøite of Lindvikskollen. This branch has also been mined for rutile, but seems to be considerably poorer ore than the major deposit. The corundum-bearing rock is also found here. The central branch is the largest; much of it is a pure white, medium-grained, granulose albitite, containing 98 % albite and a little quartz and rutile, but the color and grain size are rather variable. An alkali determination of the pure albitite (Christensen, 1954) gave 11.28 % Na_2O, 0.24 % K_2O. In three components, the rock would plot at Ab

97.5, An 1.0, Or 1.4. Other minerals present in small amount in this branch are hloritce, biotite, sericite, microcline, tourmaline, sphene, apatite, and hornblende. The microcline seems to be replacing or exsolving from albite in several thin sections, though not as oriented antiperthite.

This western kragerøite body lies conformably in biotite schists, with rather sharp contacts wherever visible. The schist is often particularly biotite-rich just outside the contact.

At the northeast corner, the large kragerøite body on Lindvikskollen wedges out abruptly, but a thin, rutile-bearing albitite dike can be traced around the end of the hill to a prospect pit on the northern edge of the large pegmatite (see map). The rock prospected here is a heavily rutile- and sphene-bearing albitite also containing considerable biotite, penetrated by veins of a pure white, granoblastic oligoclase rock (An 13) which contains isolated crystals of green actinolite (Fe/Mg = 25/75). There is more sphene, at the expense of rutile, as the white vein is approached. The contacts of this body are not here exposed. A specimen of pegmatite from this prospect, cutting the rutile-sphene rock, contains highly altered albite, black tourmaline, fibrous actinolite in a shear plane, and massive, apple-green epidote.

The large kragerøite body lies in amphibolite, and where its contact is not faulted or obscured by ground cover or later pegmatites, it is seen to be of a transitional nature. The diagram, Figure 5, p. 108, was constructed from petrological and mineralogical study of four samples from the transition zone, plus a chemically analyzed sample of «common» kragerøite from Brøgger (15, p. 188), plus values for «average amphibolite» compiled from four local amphibolites which did not show any relict gabbroic features.

As the figure indicates, the change from amphibolite to albitite is characterized by a gradual decrease in amount of femic minerals (biotite, amphibole, chlorite, tourmaline, apatite) and a parallel decrease in the An content of the plagioclase, while the amount of albite increases and the Mg/Fe ratio in amphibole increases. This transition zone is so wide in most places that an actual contact cannot be pointed out in the field; it is usually a matter of some meters. Actually a great variety of rock types are present in the contact zone, and their mineralogical properties do not always vary regularly with the dis-

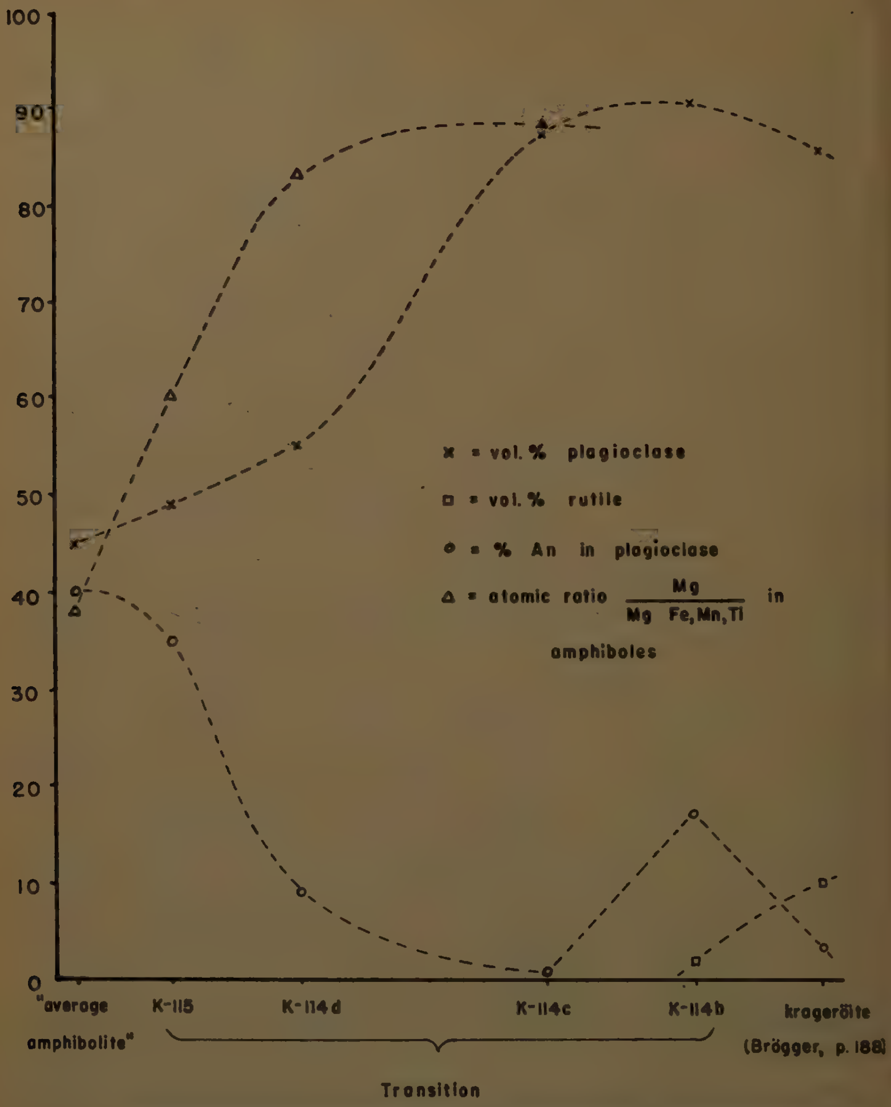


Fig. 5. Kragerøite-amphibolite transition, Lindvikskollen, west of rutile mines.

tance from either end of the system; the An content of the plagioclases plotted on the diagram illustrates this irregularity. The general trend, however, is unmistakable.

The Geologisk Museum in Oslo has in its collection a specimen of coarse-grained to pegmatitic rock from one of the rutile prospects on Lindvikskollen. The rock is predominantly albite, with some microcline and quartz and many euhedral crystals of apatite, clear brown sphene, and prismatic, green diopside. Diopside is a characteristic mineral of the contacts of other albitite bodies (see p. 133), and as it is not found elsewhere in the kragerøite or in any other plagioclase pegmatites, I interpret this specimen as coming from the kragerøite-amphibolite contact zone.

The large body of albitite which stretches with varying widths from Storkollen west to Ånevik is of a rather different character from the kragerøite. Its major mineral is again albite, but the anorthite content ranges from O to 10 %, and although the body is quite continuous (except for the erosional gap at the river) the relative amounts of the three main minerals vary greatly (see Figure 10). The rock is white to tan, inequigranular but finer-grained than the typical kragerøite, and often shows a weak gneissic to schistose structure due to large, elongated quartz grains or scattered, parallel biotite, chlorite, or hornblende. Brøgger mentions this rock (15, pp. 204 to 208) and gives two chemical analyses of it.

The albite shows the common albite twinning, and is usually slightly sericitized. Epidote or zoisite is present in some few grains, but is very subordinate to the sericite in amount.

Quartz comprises from 10 % up to at least 50 % of the rock. Its grains are large (up to 3—4 mm) to very small, and of various character. The largest are elongated, have smooth, rounded boundaries, and show undulatory extinction. Also characteristic for this body are small, rounded quartz grains poikiloblastically included in albite, microcline, or larger quartzes. A third type of quartz is irregular grains often with extremely wiggly grain boundaries; these occur in veinlets replacing the other minerals.

Microcline is also present in highly variable amounts; thin sections show a range of 0 to 23 % of this mineral. It resembles the microcline of the kragerøite in its textural relations with albite. A large majority of the thirty-six thin sections studied from this body contain less than 6 or 7 % of microcline, and it is interesting to note that the specimens containing the most microcline also contain

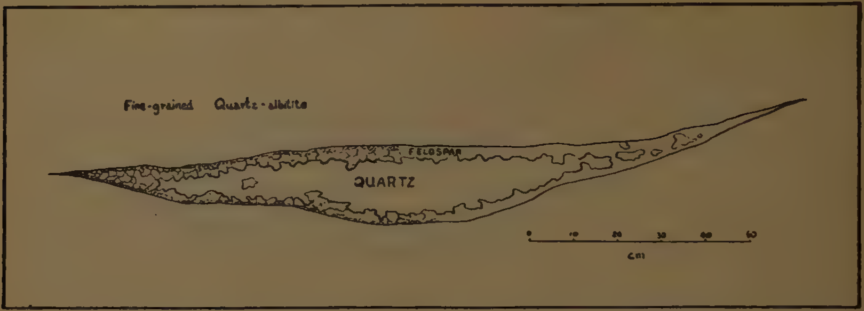


Fig. 6. Small concretionary pegmatite in quartz-albitite, west Storkollen.

considerable quartz (Fig. 10), although the inverse relationship does not hold. In nearly all cases, the degree of sericitization of the plagioclase clearly increases towards the fresh microcline patches. No systematic areal distribution of the quartz or microcline has been observed.

Other minerals occur only in accessory amounts and with irregular distribution. They include biotite, chlorite, amphibole, apatite, rutile, sphene, muscovite, epidote, zircon, tourmaline, iron ores, and prehnite (or epidote?) as lenses in biotite and chlorite. The rutile in this body does not reach the high concentrations typical of the Lindvikskollen albitite. Neither sphene nor rutile here ever amount to more than about 2 % of the rock, and commonly are considerably less abundant than that.

The coarse-grained facies described below as «plagioclase pegmatite» (p. 127) makes up a considerable portion of this large quartz-albitite body, particularly west of the Kammerfoss River. The boundaries between the two are intricate and entail only an increase in grain size. Small concretionary pegmatites with sharp contacts are also found in this body, usually containing mostly quartz (Figure 6).

The large quartz-albitite is everywhere surrounded by amphibolite or later microcline pegmatite. The albitite-pegmatite contact will be treated later under the section on pegmatites; it will merely be mentioned here that the pegmatite is evidently the younger rock.

Except for one portion, the large quartz-albitite body shows a gradual transition into amphibolite — or vice versa. The transition zone has been observed to range from less than 50 cm to many meters in width. At the narrowest places, the transition from white to dark

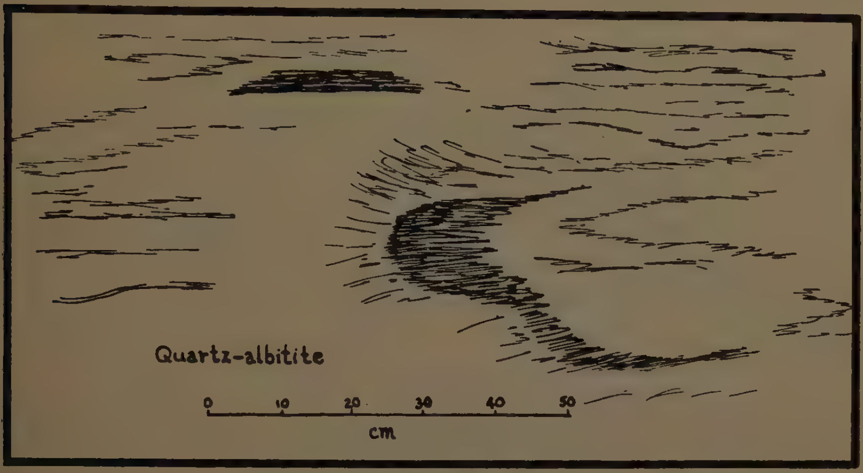


Fig. 7. «Ghosts» of amphibolite in quartz-albitite near southern contact, west Storkollen.

rock can appear very abrupt, perhaps complete within 10 cm, but a study of the mineralogy of the adjacent amphibolite shows that its plagioclase is albitic, and round quartz grains appear inside any or all of the amphibolite minerals.

The contact is never sharp, in the sense of that of a diabase dike; but a considerable length of the southern contact on the hill Sjåen is relatively sharp and cross-cutting, with only a thin (1—2 cm wide) layer of matted, light green tremolite (Mg/Fe = 90/10 mol) separating the quartz-albitite from the amphibolite, whose foliation is truncated by the contact. A small topographic valley follows this contact, usually just on the amphibolite side, for a long distance.

Elsewhere, the transitional contact is either concordant or cross-cutting. When discordant, it is always exceedingly gradual, such as towards the eastern end at Storkollen, where a large area is composed of a «transition gneiss». The transition rocks retain the foliation direction of the surrounding amphibolite. «Ghosts» of amphibolite in albitite are common near the contact, and many of these streaks have frayed ends (see Figure 7).

The quartz-albitite — amphibolite transition shows mineralogical variations closely comparable to those characterizing the kragerøite-amphibolite contact (Fig. 5). Figure 8 shows some of the most im-

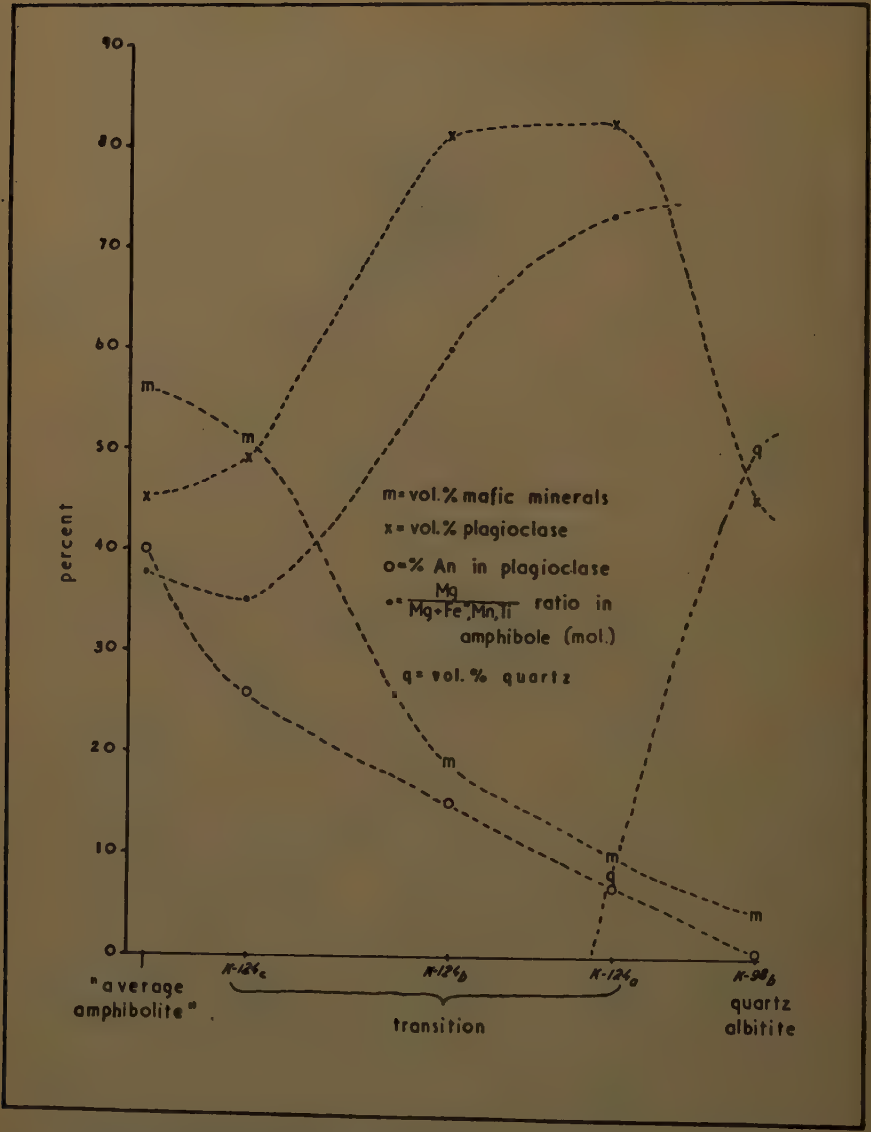


Fig. 8. Quartz-albitite-amphibolite transition, near top of hill southwest of Leirvik.

portant variables across the transition into the large quartz-albitite body at one place near Leirvik. The data were compiled from thin section study and refractive index determinations.

The general trends are seen to be analogous to those in the kragerøite contact. As the amount of dark minerals decreases, the Mg/Fe^{++} ratio in the amphiboles increases, the An content of the plagioclase decreases, and the bulk of plagioclase increases. Quartz occurs only in the albitite and the lightest zone of the transition. In a thin section of the latter, the quartz occurs as small, round grains, inside the other minerals, mafics as well as albite.

Besides the above-mentioned mineralogical changes, one other is characteristic and of interest in the albitite-amphibolite transition. A light green diopside, or more exactly salite (10 to 50 % hed.) is found in a substantial majority of these transition rocks, and is not found elsewhere, either in amphibolite or albitite. It occurs together with amphibole in most all cases, their volume ratio varying greatly. Several thin sections show the diopside altering to amphibole along cracks and other imperfections, and in a few cases only remnants of pyroxene grains remain inside larger, fresh amphiboles.

Sphene is another common mineral of these transition rocks, often surrounding cores of ilmenite or rutile.

The amphibole in the lighter rocks belongs to the tremolite-actinolite series according to Trøger's optical criteria, while that of the more amphibolitic rocks is generally a hornblende. The Mg/Fe ratio varies the same way in both types.

A small body of quartz-albitite occurs just east of the top of Lindvikskollen, apparently unconnected with the kragerøite. This body is peculiar in its content of euhedral red garnets as the major dark mineral. They range from 1 to 3 mm in size and are scattered unevenly throughout the body, probably amounting to 2 or 3 % of its volume. Its x-ray powder pattern indicates that the garnet belongs to the common metamorphic almandine-spessartine series. A little black tourmaline is also present. The plagioclase is an albite-oligoclase, An 11, and sometimes contains myrmekitic quartz near microcline grains. The plagioclase in a small pegmatitic facies is antiperthitic, with oriented lamellae of microcline.

Independent microcline (not antiperthitic in albite-oligoclase) makes up about 5 % of the rock, while quartz, with undulatory extinction, comprises about 20 %. As in the large quartz-albitite body, the plagioclase is highly sericitized where directly adjacent to microcline.

The garnet-albitite body has a transitional contact against the big pegmatite to the south, but rather abrupt contacts against amphibolite to the north and west. Along the cross-cutting western contact, a faint concentration of minute biotite, hornblende, and tourmaline crystals can be traced parallel to the contact but from two to four meters within the albitite.

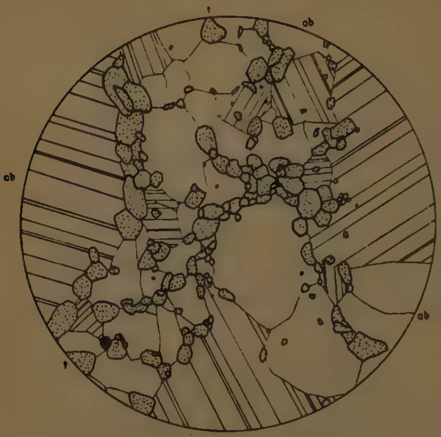


Fig. 9. K-22b. Tourmaline-albitite, at entrance to Lindvikskollen pegmatite. Ab, albite; t, tourmaline; one rutile grain. x100.

A band of albitite which strikes W to SW down to the sea from below the large pegmatite (see map) also contains red garnets, though scattered more sparsely than in the body near the top of the hill. This lower body seems to be lying on top of the amphibolite on the slope, and may have been originally connected with the upper one.

A small albitite body is exposed at the entrance to the Lindvikskollen pegmatite quarry. It is only 1—4 meters wide, but extends for a good distance east and west of the quarry entrance. Its contacts against the surrounding amphibolite are always transitional, and no connection with the large pegmatite can be seen. This albitite body contains a little rutile ($\sim$ 1 %), unevenly distributed light brown mica (0—8 %), and several percent of very small grains of a black tourmaline arranged in a net-like pattern in the granoblastic albite matrix (Figure 9). The tourmaline is a common schorl with strong pleochroism in brown, and refractive indices $\varepsilon = 1.633$, $\omega = 1.664$. The albite is twinned after the albite law and occurs in slightly sericitized grains about 1—2 mm across. In the vicinity of the tourmaline veinlets the albite is recrystallized into smaller, less altered grains. Octahedral pyrite crystals up to 1 mm in size were observed on a joint plane (?) in the rock. The rock has a remarkable appearance

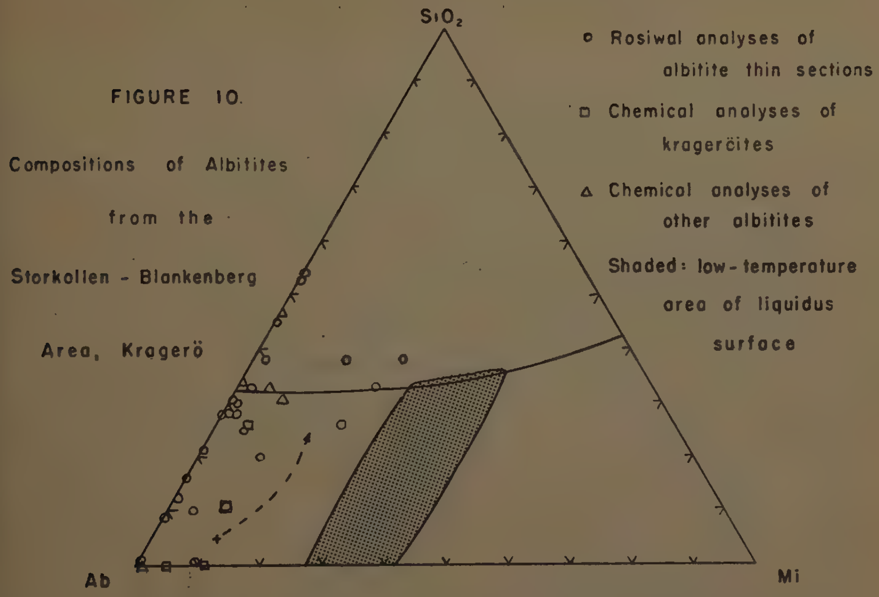


Fig. 10. Compositions of albitites from the Storkollen—Blankenberg area, Kragerø.

attributable to the tourmaline veinlets, which have obviously been formed after the formation of the albitite in which they occur.

The transition to amphibolite consists of successively darker rocks containing increasingly calcic plagioclase, biotite, eventually amphibole as the amphibolite is approached, tourmaline, and accessoric apatite. The diagram, Figure 11, shows the trends of the major mineralogic variations across this transition. The rock is completely recrystallized, all minerals being fresh (except for slight sericitization of the feldspar).

The tourmaline in this contact zone is of especial interest. It occurs in well-formed porphyroblastic crystals up to at least 2 cm in diameter, black with a shiny vitreous luster on the crystal faces. The crystals are approximately equidimensional, showing short, unstriated prism and rhombohedral faces. The refractive indices are $\varepsilon = 1.625$, $\omega = 1.643$, uniaxial negative, with strong pleochroism; E = pale blue-green, O = olive-brown. A partial chemical analysis of this tourmaline (Christensen, 1954; see Table I) and a spectrographic

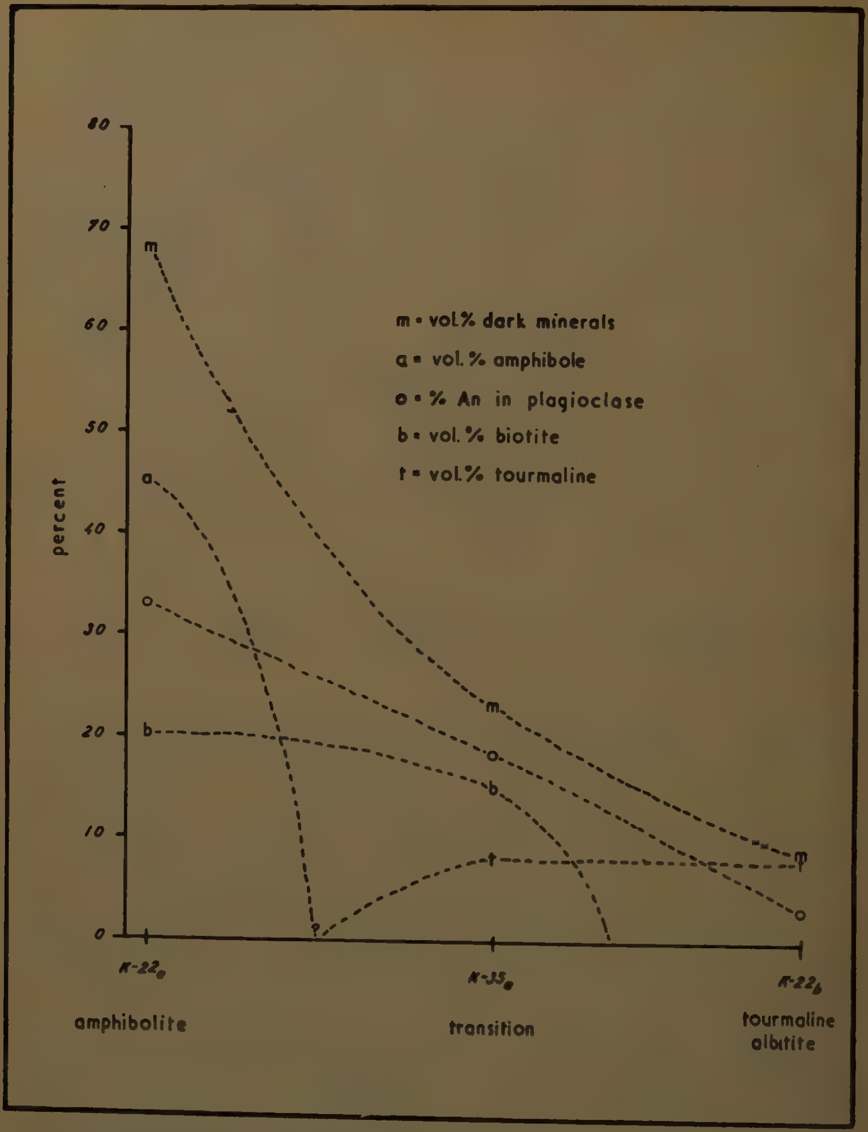


Fig. 11. Tourmaline-albitite — amphibolite transition, entrance to Lindvikskollen quarry.

investigation indicate that this mineral is a magnesium-rich variety, belonging to the uvite-dravite series. The spectrograph showed no trace of lithium. The transition from schorl in the albitite to Mg-tourmaline in the contact zone has not been studied.

This is a new locality for magnesian tourmaline. OFTEDAL (25, p. 30) lists Melkedalen in Ofoten, Arendal, and Modum as previously reported Norwegian occurrences.

The tourmaline in the corundum-bearing kragerøite near the top of the hill, although fine-grained, has similar pleochroism and refractive indices ($\varepsilon = 1.624$, $\omega = 1.651$), and is most likely also a magnesian tourmaline.

Many smaller, narrow, and more or less longitudinally extended dikes of various sorts of albitite crop out in the map area. Like the large bodies, they contain varying amounts of albite, quartz, and microcline, which three minerals make up the great bulk of the rocks. These dikes are both concordant and discordant, and have as a rule relatively sharp contacts, although some, as Brøgger noted on Langø in the skjærgård to the east, have the typical diopside-bearing transition gneiss (15, p. 299). Most all of them show structures parallel to the structures in the surrounding amphibolite or schist, many of which are formed by the preferred orientation of new minerals (quartz, tourmaline) foreign to the dark rock. A common feature is foliation produced by tiny parallel lenses of undulatory quartz (comprising from 20 to 45 % of the rock); perhaps as common is lineation produced by tourmaline needles (schorl, comprising up to 3 % of the rock) oriented parallel to the regional lineation. Some dikes send apophyses into the country rock, and some develop coarse grain size where they are widest. Some contain streaks of dark minerals (biotite and actinolite). Other minerals encountered are sericite, apatite, garnet, black ore, and chlorite, each in only accessoric amount.

Marked inequality of grain size is a common feature of these dikes (except for the most monomineralic ones). Some have albites up to 3 mm across, with much smaller quartz and microcline grains interstitial or enclosed by albite. One dike contains perthitic microcline crystals up to 2 cm across in an otherwise fine- to medium-grained groundmass of albite, quartz, and microcline. The microcline, here comprising up to at least 20 % of the rock volume, often shows smooth, rounded contacts against the other minerals, but jagged edges, parallel

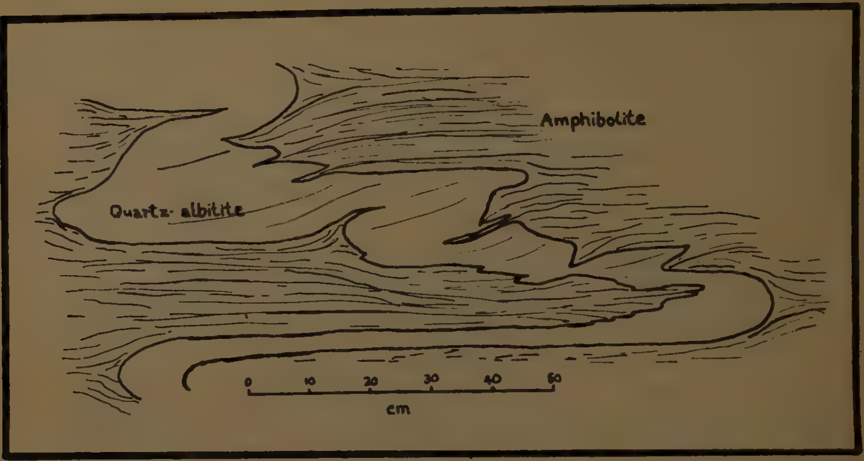


Fig. 12. Small, deformed quartz-albitite vein in amphibolite, west Storkollen.

growth, increasing sericitization, and myrmekite are also often seen at albite-microcline contacts (as is the case with the large microclines mentioned above). The plagioclase is usually an albite (measured values An 0, 3, 8, 10, etc.), but one narrow cross-cutting dike with much quartz oriented at an angle to the sharp contact contains oligoclase to andesine, with measured values ranging from An 17 to An 34. The higher value approaches that of the adjacent amphibolite.

A small, highly distorbed albitite vein on the west shoulder of Storkollen shows sharp, cross-cutting contacts against the amphibolite. It contains a faint gneissic structure which is roughly parallel to that of the surrounding rock. The amphibolite foliation is bent by the growth (or existence?) of the vein, but the general discordance is obvious (see Figure 12).

A small occurrence of fine-grained quartz-plagioclase rock was observed in a road cut of the Havna road in the southwestern corner of the town (east of the map area). Only about two meters long and of various width, it is centered around a fissure in the dark, gneissic amphibolite. The most striking feature of its appearance is the obvious suggestion of replacement it gives, with its very irregular shape, always transitional contacts, and retention of the structure of the amphibolite in the form of planar blotches of small black ilmenite grains. This spotted rock is seen only immediately surrounding the fissure, and the ilmenite lenses can be traced into the amphibolite, where they become sphene.

Microscopically the white rock was found to consist 85 % of fine- to medium-grained granulose oligoclase-andesine (An 30), and 10 % of small, rounded quartz grains lying in and between the plagioclase crystals. The remaining 5 % is mostly ore, with small amounts of apatite, sphene, hornblende, biotite, and chlorite. Aside from the streaks of ore and the An content of the plagioclase, this rock closely resembles the quartz-albitites of the map area to the west.

Pegmatites. A great number of dikes, pods, and more irregular bodies of pegmatite occur in the mapped area, of all sizes up to what Bjørlykke reported in 1937 (9) as being the largest in Norway. They can be divided mineralogically, structurally, and genetically into two general types, which I shall here call, in oversimplification, microcline-pegmatites and plagioclase-pegmatites. BRØGGER (15) has investigated a few plagioclase pegmatite dikes from Kragerø, and OLAF ANDERSEN (1, 2, 3) and HARALD BJØRLYKKE (9, 10, 11) have done much work on the microcline pegmatites in the present area, Andersen concentrating on the feldspar and Bjørlykke on the rare minerals. The latter author also devised a scheme of classification for the Norwegian pegmatites, based on their mineralogies.

The microcline pegmatites range in size from small to large, and are mostly very coarse-grained except close to their contacts. They occur as both concordant and discordant bodies, the same pegmatite often showing both types of relations to its country rocks. Two appear to be completely surrounded by albitite; the others lie in amphibolite.

The largest microcline pegmatites have all been quarried at various times for feldspar and, more rarely, for quartz. Besides microcline-perthite, graphic granite, and quartz, they contain considerable amounts of plagioclase (albite and sodic oligoclase) and tourmaline, both relatively scarce in other Norwegian pegmatite areas, and biotite, magnetite, amphibole or pyroxene, apatite, and yttrotitanite (keilhauite). This abundance of calcium-bearing minerals places these pegmatites in Bjørlykke's Ca-rich Group (7). The three largest bodies are famous for their rare minerals, mostly rare-earth varieties, of which alvite $(Zr,Hf)SiO_4$ and orthite (allanite) are the most widespread.

The largest pegmatite is the Lindvikskollen—Kalstad body, which extends from the very top of Lindvikskollen eastward diagonally down the slope, finally reaching the sea almost due south of Storkollen's summit (see map). It has been quarried extensively all along its length; two of these prospects, the Lindvikskollen and Kalstadgangen quarries, are famous for their rare minerals. Its southern contact is sharp against amphibolite, and dips north at from 10 to 40 degrees except for the extreme eastern end which is close to vertical. At one place near the eastern end, it lies on a fault plane (Figure 2), but in most exposures, such as at the entrances to the three westernmost quarries, the pegmatite has a sharp, wavy contact. The pegmatite is here fine-grained next to the amphibolite, rapidly becoming coarse-grained with development of biotite, actinolite, and albite crystals perpendicular to the contact, in a zone up to 5 cm wide. The contact is not well exposed near the middle where the microcline-pegmatite lies against plagioclase-pegmatite.

In the wall of the quarry next to the east from the Lindvikskollen quarry, a large block of amphibolite with sharp contacts can be seen completely surrounded by pegmatite. Its foliation is not parallel to the amphibolite foliation outside the pegmatite.

The pegmatite's north contact dips north, but at an unknown angle. At the west end the pegmatite shows a seemingly completely gradational, unmappable contact against the adjacent kragerøite and the garnet-albitite body, but a specimen taken from inside the rutile mine shows large microcline crystals poikilitically including and apparently replacing the small kragerøite grains. As such microclines are unknown from elsewhere in the kragerøite, this specimen has probably come from the pegmatite-albitite contact, and indicates that the pegmatite is the younger of the two. Elsewhere, the north contact can be mapped, but is nevertheless gradational over some few centimeters whether against amphibolite, albitite, or plagioclase pegmatite. It is definitely discordant with all three. Much of the amphibolite on the north side is full of small albitite and plagioclase-pegmatite stringers and dikes, and resembles the «transition gneiss» mentioned above.

The Kalstad-Lindvikskollen pegmatite contains a rich assortment of minerals. A complete list of minerals known at present from this body follows, with comments on modes of occurrence.

Microcline-perthite makes up the bulk of the pegmatite. The color varies from greenish to reddish to buff. It occurs commonly in large crystals, (including euhedral Carlsbad twins), some attaining a width of several meters as exposed in the quarry face.

Quartz occurs in small grains to large masses several meters across, and in considerable amount.

Plagioclase of white to gray to tan color is a major constituent of this pegmatite, and its composition ranges between An 5 and An 15.

A large specimen full of lustrous, prismatic crystals of *scapolite* up to 3 cm long, with black pyroxene and dark brown sphene, was collected at the Lindvikskollen quarry in 1953. A refractive index determination gave $\omega = 1.551$, $\varepsilon = 1.542$, indicating a composition of about 80 % Ma. The relation of this loose block to the pegmatite itself is not certain. Schetelig in 1915 (29) mentioned another scapolite ($\omega = 1.567$, $\varepsilon = 1.550$) supposedly from a Kragerø pegmatite, but the exact locality is unknown.

Tourmaline occurs in rather large quantities. It is a common black schorl type.

Apatite was found in blue-green, prismatic crystals up to 3 cm across. According to Bjørlykke (9) it contains small amounts of rare-earth elements.

Sphene, an yttrium-bearing type, is present in considerable quantities. It is brown to gray with an adamantine luster, but is sometimes highly altered.

Biotite is more common in the Lindvikskollen quarry than elsewhere in the dike. It is dark brown, altering around the edges to chlorite, and occurs in large platy growths several meters across by only a few centimeters thick, branching apparently perpendicular to the (110) faces.

Magnetite occurs abundantly in roughly spherical crystals showing perfect octahedral cleavage.

Ilmenite is found as platy intergrowths with plagioclase, the alternating lamellae ranging from 1 to 15 mm in thickness. Rare minerals often occur in the acute angles where pairs of ilmenite plates join.

A *hornblende* from near the amphibolite contact was found by refractive indices to have an Mg/Fe″ at. ratio of 70/30. An amphibole from the dump was closely associated with magnetite; its optical properties are $\alpha = 1.659$, $\beta = 1.675$, $\gamma = 1.680$, $-2V \sim 70°$, $Z:c = 21°$.

Muscovite is found in small quantities as a relatively late mineral in the Lindvikskollen quarry, and also as small (up to 5 mm across) rounded prisms with a peculiar greenish color, associated with *calcite*, *clay minerals*, quartz, and *pyrite* in a late-stage breccia zone and fissure fillings in the Kalstadgangen quarry.

The pyrite has the pyritohedral form, often with penetration twins, in crystals up to 2 cm in diameter.

BJØRLYKKE (9) observed small fragments of pink calcite embedded in microcline.

Small amounts of *phenacite* have been collected from this pegmatite, as colorless, prismatic crystals.

The following dark minerals were determined provisionally by their x-ray powder patterns, heating the metamict specimens to 700° or ~ 1030° C.

Euxenite occurs in seemingly late-stage fractures, mostly as irregular masses. It is black, shiny, and metamict.

Orthite (*allanite*) is found in large quantities in this pegmatite as brown, shapeless masses and blackish, often tapering prismatic crystals up to at least 10 cm in diameter. Both kinds are covered with a tan alteration product, and are partly metamict. The unheated powder of the first variety gives a few unrecognizable lines on an x-ray film; the second gives a recognizable orthite pattern. A spectrographic investigation confirmed the identification of the first variety as orthite. According to Goldschmidt (19) the orthite from Kalstadgangen contains La, Ce, Pr, Nd, Sm, Gd, Dy, Er, and Yb.

The Lindvikskollen quarry is the original locality for the mineral *hellandite* (12). It occurs in small, prismatic crystals, usually much altered.

Bjørlykke records observing *thorite* (possibly *orangite*) in small red nodules in microcline, and also lists *alvite* as occurring in this dike.

In the course of investigation these dark minerals by x-ray powder patterns, I came across a specimen of *fergusonite*, which, to my knowledge, has not been heretofore recorded from Kragerø pegmatites. The specimen is brownish black, shiny, and metamict. It occurs together with yttrotitanite, euxenite, tourmaline, and microcline.

A brown mineral, previously unknown, was discovered by C. T. Johne of Kragerø in the Kalstad pegmatite a few years ago. X-ray, chemical, and spectrographic investigations of similar material collected by Johne from a rare-mineral pegmatite at Gryting, Gjerstad, indicate that the new mineral has the gadolinite-datolite structure, but contains a large amount of Ca in place of the Fe of gadolinite.[1] It occurs at Gjerstad closely associated with gadolinite, probably as an alteration product.

The other famous pegmatite body in the map area is the Tangen pegmatite, which was owned and worked by the late mineral collector Peder Tangen. It lies on the east bank of the Kammerfoss River near the northern boundary of the map area. It is much smaller in outcrop than the Kalstad—Lindvikskollen body, measuring only about 40 by 50 meters. The surrounding amphibolite varies greatly in strike and dip over short distances, and was evidently influenced by strong, localized stresses.

The pegmatite-amphibolite contacts are mostly cross-cutting and fairly sharp, and are characterized by the formation of a black biotite in the amphibolite. A thin section of one such contact specimen showed considerable sphene and apatite, and pure albite and quartz penetrating the ferromagnesian minerals. The larger feldspars show evidence of strain.

The Tangen pegmatite differs from the Kalstad—Lindvikskollen body mainly in that it consist to a great degree of the blady variety of albite, *cleavelandite*. This mineral occurs in large radial aggregates and thin fissures in the surrounding *microcline*-pegmatite. It is pure white to gray, and has the molecular composition Ab 96.3, An 0.7, Or 0.9 (rest 2.1), according to Andersen (2, p. 43).

The original *plagioclase* in this pegmatite contains varying amounts of anorthite, from O to about 15 %. Andersen (1) states that these plagioclases usually are antiperthitic, with between 3 and 10 % of pure microcline in thin stringers, and none dissolved in the groundmass.

Quartz is a common mineral here, occurring both in the microcline and cleavelandite facies.

Black *tourmaline* is abundant, sometimes as intimate intergrowths with quartz.

Magnetite balls, up to 3 or 4 cm in diameter, are scattered widely in the microcline-pegmatite. Where the latter has been replaced by cleavelandite, the magnetite is commonly changed to *hematite*. The magnetite contains considerable Ti and Mn (Bjørlykke, 9).

Pyrite in twinned pyritohedra occurs here, as well as small lumps of *chalcopyrite*.

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[1] T. F. W. Barth, K. Heier, personal communication 1954.

A *pyroxene* was collected by Andersen in 1923 from the Tangen pegmatite; its optical properties identify it (after Trøger) as an augite, containing about 20 % of the aegirine molecule.

Considerable well-formed *phenacite* has been collected from this locality, this and the Kalstad-Lindvikskollen pegmatite being the only known occurrences of the mineral in Norway.

Topaz labeled «Tangen, Kragerø» is found in the collection of the Mineralogical Museum of the University of Oslo, but none of the recent investigators has found any in the pegmatite itself.

Yttrotitanite is commonly found here associated with the other dark, rare-earth minerals. *Alvite* appears as good-sized clumps of gray-brown crystals, usually with curved terminal faces. Much *columbite* has been collected, in well-formed crystals weighing up to 50 kg. According to Bjørlykke (9), it contains more Mn than Fe.

Betafite, *thorite*, and *orangite* occur together, in considerable amount The betafite is metamict, with a waxy luster and an orange to brown color. The thorite is red to brown, not completely metamict, and also has a waxy luster. The orangite is metamict, with a resinous appearance and orange to brown color.

BJØRLYKKE (11) also lists *orthite*, *euxenite*, and *hellandite* as occurring in the Tangen pegmatite.

The Sjåen pegmatite (also called Dalene, or Høisjåen) crops out at the edge of the west-facing cliff at the top of the hill Sjåen, at an elevation of 150 meters (see Plate XVII). It has the form of an elliptical pod, extending almost vertically down into the hill. It seems to be completely surrounded by a large quartz-albitite body, against which it has fairly sharp contacts.

The Sjåen pegmatite closely resembles that at Tangen, and may well be connected with it underground. It has undergone the same cleavelandite-quartz mineralization, and contains a similar mineral suite: *microcline-perthite*, *plagioclase*, (An 5 and An 11 were determined by refractive index), *quartz*, *magnetite*, *tourmaline*, *aegirinaugite* (about 28 % aegirine molecule), *apatite*, *yttrotitanite*, *euxenite*, *betafite*, and according to Bjørlykke (9, 11), *alvite* and *orthite*. An unusually coarse graphic granite is common, consisting of intergrowths of quartz with microcline-perthite.

Several smaller microcline-pegmatites are also shown on the map. One of these, cropping out near the top of the south slope of Stor-

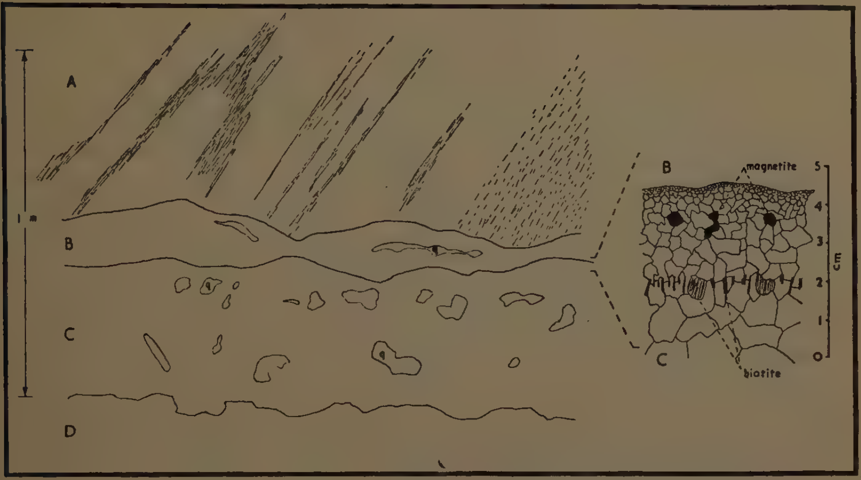

Fig. 13. Contact of pegmatite with albitite-amphibolite transition gneiss, in quarry just west of Dalene pond.

kollen, is particularly dike-like in form. It has been worked for feldspar. It is about 15 m wide and stretches for over 100 m along the hillside; its eastern end is blunt and abrupt, whereas the northwestern end tapers out to nothing. The dike has moderately to very sharp contacts, dipping steeply to the north and northeast. One contact, discordant against the amphibolite, has a contact zone about 1—2 cm wide which weathers out in relief. This was found to consist mostly of chlorite and albite (An 8), filled with small scraps and grains of sericite, calcite, epidote, and rutile. At another point, the pegmatite-amphibolite contact shows a wider reaction zone up to 20 cm in thickness, and of quite a different character. It contains black tourmaline prisms in a quartz matrix, strongly pleochroic hornblende, apatite, biotite and chlorite including lenses of prehnite, pyrite, highly altered plagioclase (fresh where next to the chlorite), scapolite with scraps of opaque ore near biotite, calcite, and tiny zircons in the biotite.

The pegmatite proper contains *microcline-perthite*, *plagioclase*, and *quartz* (often in large masses), *biotite*, *magnetite*, much *tourmaline*, and *orthite* and *fergusonite*.

A pegmatite which crops out in quartz-albitite just west of the Dalene pond has also been worked. It has an irregular shape, and apparently dips steeply into the hill. The contacts are well exposed in a few places, and are especially interesting (see Figure 13). The country rock is a light phase of the albitite-amphibolite transition gneiss, containing albite-oligoclase, quartz, diopside, and hornblende. Its dark minerals are here slightly concentrated in bands, giving the rock a gneissic appearance. (A in Fig. 13). About 10—20 cm from the actual pegmatite contact, this structure is cut off by a zone of structureless albitite with a few quartz lenses parallel to the contact. (B). At the contact proper, and going into the pegmatite, the grain size suddenly grows from about 1 mm to about 4—5 mm, and there is an abundance of magnetite crystals in this zone, which is about 2 cm wide. Then appears a narrow zone of small biotite flakes which have grown perpendicular to the contact, and there follows a typical pegmatite zone (C) with coarse-grained quartz and feldspar which gives way to a large quartz mass (D) 40 cm in from the contact.

Apophyses of pegmatite into albitite were also seen. One contact specimen resembles that described from the pegmatite-kragerøite contact. It consists of ~ 1 mm rounded grains of albite (An 8), salitic pyroxene, biotite, sphene, apatite, and zircon «floating» poikilitically in a groundmass of large (2—5 cm) microcline crystals.

Minerals to be found in this pegmatite are *microcline-perthite, quartz, plagioclase* (An 0 to 11), *black tourmaline, hornblende, biotite, sphene, magnetite,* and *calcite.* The calcite occurs as large crystals with pure albite and quartz in a vein. Rare minerals have not been observed here.

The smaller coarse-grained microcline-pegmatites usually have amphibole, magnetite, sphene, and alvite as the dark minerals.

Several microcline-pegmatites in this area do not show the very coarse grain size which is so typical of those described above. These, whose grains range mostly between 0.5 and 2.0 cm in diameter, contain as a rule few dark minerals, mostly biotite partly altering to chlorite, but also commonly euhedral magnetite, and sphene. They are usually cross-cutting bodies, but sometimes they follow the boundary between albitite and amphibolite. A specimen from such a contact between kragerøite and a small pegmatite on Lindvikskollen shows again large microclines including the crystals of the fine-grained rock. Similar relations are found at the pegmatite on the western end of Storkollen just above the pond (see Figure 14).

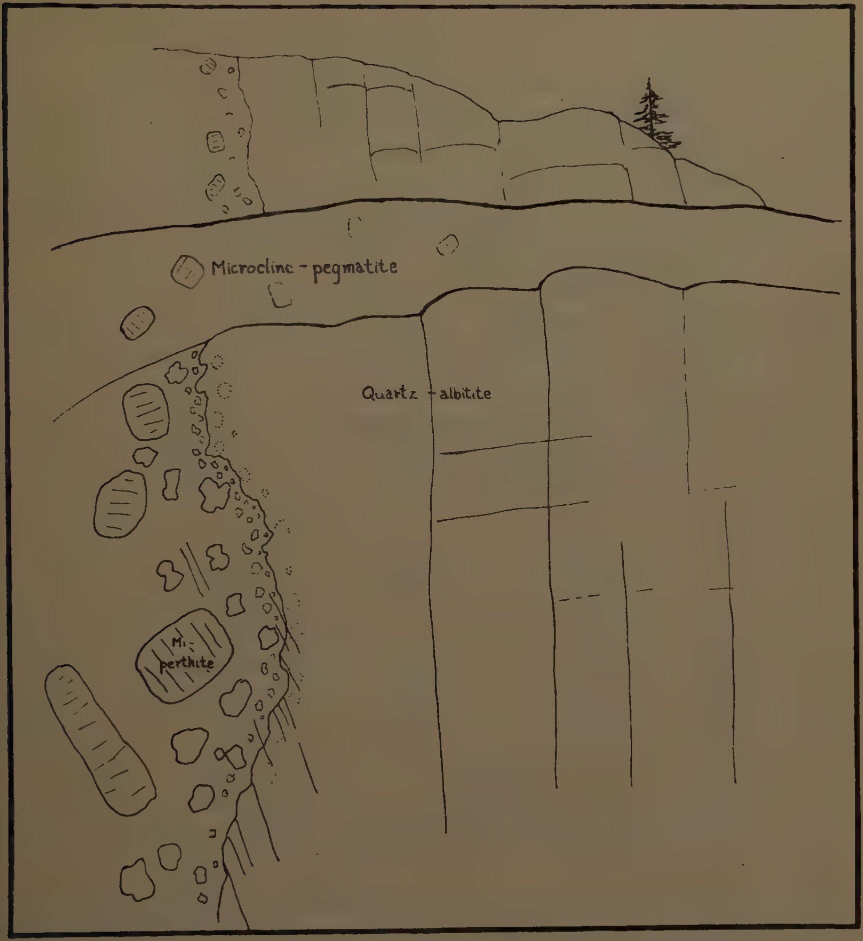

Fig. 14. Contact of pegmatite with quartz-albitite, west end of Storkollen.

The plagioclase-pegmatites never attain the large grain size of some of the microcline-pegmatites; most grains are between 0.3 and 3.0 cm across. The bodies are extremely irregular in shape, occurring both as coarse-grained stringers and masses without sharp boundaries in albitite and as independent, dike-like bodies. They consist mostly of an albite or albite-oligoclase, with considerable quartz and lesser amounts of microcline, biotite, hornblende, chlorite, apatite, and tourmaline. This mineralogy closely resembles that of the albitites, both in phases and proportions, and I consider these plagioclase-pegmatites to be merely a coarse-grained facies of the albitite suite. A more coarse-grained pegmatite within the main body of kragerøite in Lindvikskollen offers a fine example of this relationship. Although adjacent to the large microcline-pegmatite, the kragerøite pegmatite contains only the minerals of the surrounding kragerøite, and in approximately the same proportions; thus, albite, rutile, quartz, biotite, pyrite, apatite, and sphene.

Iron Mineralization. A series of small iron oxide deposits of varying character, size, and value occurs in a roughly east-west line across the map area. Many small to medium-sized prospects have been worked; one tunnel has been driven into the northwest corner of Lindvikskollen and a considerable volume of ore stoped out (see map). These mines, called the «old Kalstad iron mines», have not been in operation for a number of years. The ore minerals are magnetite and hematite, introduced together with quartz, calcite, and pure albite, in a stratiform zone. The ore minerals occur in a number of different ways: rich disseminations in biotite schist (often with specular hematite plates parallel to the schistosity); large, striated, tabular hematite crystals in quartz lenses; disseminations in small quartz-albitite dikes; frothy mixtures of magnetite and calcite; grainy, bedded concentrations of hematite and magnetite in amphibolite and schist; and so forth.

An amphibole close to a small magnetite bed from the tunnel was found by optical means to have an Fe''/Mg at. ratio of 73/27, unusually high in iron.

Concentrations of magnetite and hematite occur in pegmatite as well as amphibolite and schist along the «fissure», indicating a relatively young age for the iron mineralization. At the old Kalstad iron mines, the schist shows extreme evidence of «stretch-brecciation», probably the result of stresses imposed after the period of deeper, more plastic deformation, and possibly related to the introduction of the iron minerals.

Genesis of the leucocratic rocks.

All observers seem to agree on the origin of the scapolite and apatite deposits of the Kragerø area. Their close association in space and time with the gabbros, the autometamorphic scapolitization of

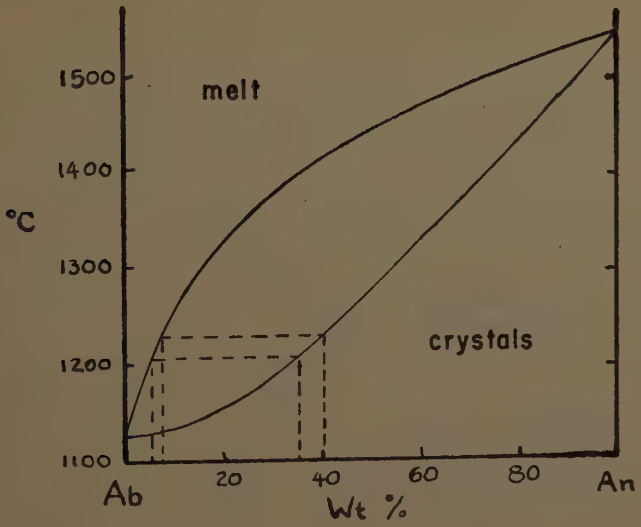

Fig. 15. Plagioclase melting diagram (after Bowen, 1913) showing possible relationship between gabbros and albitites.

some of the gabbro bodies, and the volatile nature of the constituents (P, Cl, F, OH, etc.), all suggest that gabbro magma was the ultimate source of these mineral deposits.

The albitites present somewhat more of a problem. Previous workers (Brøgger, J. Bugge) have here again pointed to the gabbros as the source of most if not all of them, citing mainly the close space-time association of albitites and gabbros throughout the Kongsberg-Bamle formation. The albitites would thus represent the residual, intergranular fluid of nearly-crystallized gabbro, squeezed out by orogenic movements and thus intruded as dikes into the surrounding sediments.

Such a hypothesis is admirably supported by some of the available information. In Figure 15, the plagioclases of the gabbros and albitites have been plotted on Bowen's experimental liquidus-solidus curves for plagioclase. The zoned plagioclases of the gabbros regularly have outer rims of the composition An 35 to 40. According to Bowen's curves, the last remaining liquid in equilibrium with these rims would be an albite of the general composition of the albitites (see Fig. 15). The anorthite content of the plagioclase rims of the gabbros varies somewhat, and so does that of the albitites, but the graphical relationship is evident.

The other major reason for attributing the albitites to the gabbros is the absence of any other suitable magmas of which they might be differentiates. The large granite plutons in the Kongsberg-Bamle formation are assumed to be younger than the albitites, and at any rate it is difficult to imagine a method of magmatic differentiation by which a granite could give rise to a nearly monomineralic, albitic product.

On the other hand, the present investigation shows that the composition of the albitites (except, perhaps, for the Lindvikskollen kragerøite) is so variable, even within a single body, that its explanation as a low-melting residual liquid of a gabbro or even several gabbros also becomes difficult. Figure 10, p. 115, is a triangular diagram of the system SiO_2 — $NaAlSi_3O_8$ — $KAlSi_3O_8$ (after SCHAIRER, Jour. Geol. 1950) with the compositions of several of the kragerøites and other albitites plotted on it. These highly leucocratic rocks are rather accurately represented by such a diagram.

The very last liquid remaining in the course of crystallization of a gabbroic magma would be expected to have a composition projecting in the low-temperature trough indicated by the shaded area on the diagram. None of the albitites and quartz-albitites studied plot in the low-temperature composition trough; all lie to the side away from potash feldspar. A few are seen to lie close to the albite-quartz eutectic and cotectic, but the large majority correspond to no kind of low-temperature composition. Analyses of Kragerø gabbros show a markedly low potash content; thus, any residual differentiate would be expected to approach the low-temperature trough from the albite side, not the orthoclase side. The plotted albitites do indeed fall on the albite side of the minimum trough, but as some potash is present in all the gabbros, the residual liquid would be expected to contain at least as much potash, if not more, as the «parent magma». In the Ab — SiO_2 — Or system, a liquid of composition such as shown by $\approx$ on the diagram would crystallize out alkali-feldspar with increasing Or content as the temperature is lowered, the crystals always being more sodic than the liquid in equilibrium with them. The liquid takes the course shown on the diagram, while the crystals move towards the minimum-melting composition of alkali-feldspar at Ab 65, Or 35 (assuming a temperature above the solvus). Thus the residual liquid of a gabbro would be expected to become relatively enriched in potash as albite crystallized. The diagram shows little evidence of this; a large preponderance of the Kragerø rocks fall on or very close to the silica-albite join.

The abundance of quartz-albitites plotting far into the quartz field also can be counted as evidence against an origin as the residual liquid of a gabbro magma. The available gabbro magmas crystallized abundant plagioclase and only very minor and occasional associated quartz; discounting the potash component, a residual liquid from such a magma would have to fall somewhere on the Ab — SiO_2 join between Ab and the albite-quartz eutectic, and never towards the SiO_2 corner from this eutectic.

It must be kept in mind that the gabbros were intruded before or during the early stages of the regional metamorphism of the Kongsberg-Bamle formation, and any comagmatic intrusions would be expected similarly to have undergone metamorphism. As has been mentioned above, the various Kragerø albitites do show linear or foliar structure, generally in the form of elongated grains or trains of quartz but also trains and schlieren of rutile, and oriented micas, hornblende, and tourmaline, parallel to the regional structures and not the local contacts. The quartz everywhere shows undulatory extinction. The complete absence of chill structures, the equigranular allotriomorphic texture (in the purer albitites) and the preponderance of conformable contacts cannot then be taken as evidence against an igneous origin for these rocks, considering this later metamorphism.

A brief résumé of the field relationships is of value at this point. Although some of the smaller albitite bodies are narrow, sharply defined, and cross-cutting, most easily explainable as dikes, the two largest bodies show markedly different contact relations. The southern contact of the large kragerøite body is obscured, while that of the large quartz-albitite body to the north is through most of its extent sharp; that is, its southern albitite-amphibolite transition is complete over a distance of a few centimeters or so. The northern contacts of both bodies are characteristically gradational, the change being complete only over a considerable distance. That these bodies could have been intruded as conventional dikes seems then highly unlikely.

W. C. Brøgger (15) and J. Bugge (18) attribute some of the Kongsberg—Bamle albitites to replacement processes. «The occurrences within the Kragerø region mentioned above of 1) dykes and veins of albitite, and 2) of banded, albite-amphibolites, undoubtedly originated by the metasomatism of former scapolite-rocks, certainly prove that a number of the albite-rocks of the Kragerø region are of secondary, metasomatic origin.» (Brøgger, 15, p. 236). «Closer studies show that during the last part of the period of migmatization, an extensive albitization has taken place in the rocks in large parts of the Kongsberg-Bamle formation.» (Bugge, 18, p. 49).

As the various possibilities for a magmatic origin of the Kragerø albitites have been found to be somewhat less than satisfactory, the possible role of metasomatism will now be considered.

The Gibbs Phase Rule states that the number of independent variables in a system in equilibrium cannot exceed the number of components plus P, T, minus the number of phases; or, $f = c + 2 - \varphi$. V.M. Goldschmidt's Mineralogical Phase Rule, $\varphi = c$, merely states that at any random, P, T, the number of phases will not exceed the number of components. D.S. Korjinsky extended the application of the Phase Rule to systems with mobile components; where the μ_m, or chemical potential of each mobile component, is variable, then the Gibbs Phase Rule simplifies to $f = c_m + 2$ (variance equals the number of mobile components plus P, T) and $\varphi = c_f$ (the number of phases does not exceed the number of fixed components).

Thus in any metasomatic process, where one or more components are mobile, equilibrium mineral assemblages will tend to be simplified, not complicated; the more components are mobile, the fewer phases there can be.

In their highest development, the albitites at Kragerø attain one of the simplest mineral assemblages imaginable — all albite. Their granoblastic texture indicates that they have reached textural equilibrium, which in turn implies (though does not guarantee) attainment of chemical equilibrium. Thus the albitites seem theoretically amenable to consideration as metasomatic rocks.

Many of the contact phenomena of the albitites are easily explainable by metasomatic processes. The gradual variation in the compositions of solid-solution minerals, such as plagioclase and amphibole, were necessarily accomplished by action of this sort. This presence of major minerals with variable compositions helps to explain the general absence here of sharp metasomatic «fronts» which are to be expected when only fixed-composition minerals are involved. With the increase of Na_2O and SiO_2, the plagioclase, being the major phase at high metamorphic grades capable of holding much soda, becomes more and more albitic while the CaO thus released changes hornblende into diopside (found only at albite-amphibolite contacts). These reactions might be expressed thus:

$$Na_2O + 4SiO_2 + \underset{\text{An}}{CaAl_2Si_2O_8} \rightarrow \underset{\text{Ab}}{2NaAlSi_3O_8} + CaO$$

$$3CaO + 2SiO_2 + \underset{\text{Actinolite}}{Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2} \rightarrow \underset{\text{Diopside}}{5Ca(Mg,Fe)Si_2O_6} + H_2O$$

Eventually the diopside too is removed. Sometimes, as in the little plagioclase body on the Havna road, diopside is not formed and plagioclase replaces hornblende directly.

When it is recalled that the albitites have undergone metamorphism, these contact phenomena are seen actually to be equally explainable by the original reaction of mobile, albitite-forming ions with the amphibolite, or by the reaction of already-present albitite (whether magmatic or metasomatic) with adjacent amphibolite, during subsequent metamorphism. In either case, mobility of ions and metasomatic action are evident, at least in the contact zone, and the real problem becomes, as in most cases of «granitization», to what extent beyond what we actually observe, was metasomatism operative?

As the evidence afforded by the contact phenomena cannot be safely extrapolated to provide conclusions as to the origin of the albitites themselves, the albitites themselves must provide the answer if any is to be found.

The source of the albitic material, whether it became emplaced as magmas or by metasomatism, seems inescapably to be the gabbroic magmatic complex (if the source is assumed to be in evidence). We have seen how residual magmas with compositions of most of the albitites are highly unlikely if not impossible, and we have seen that a monomineralic rock such as the purest Kragerø albitites is just what might be expected to result from a high degree of ion mobility. Metasomatism is thus the alternative which seems best suited to the observed facts.

Some special cases deserve particular notice. Many of the smaller albitite bodies (*e.g.* north side of Lindvikskollen) are narrow, persistent, and dikelike in form, and show clearly cross-cutting relations. These often turn out to be the ones compositionally most amenable to a magnatic explanation; that is, they lie away from the quartz-albite join of Fig. 10, towards the cotectic or the low-temperature area. For these it is perhaps not necessary to propose a metasomatic origin; a residual magma would answer quite well enough.

The problem at once arises, what did the albitites replace? The large, and varying, amount of quartz in the large quartz-albitite body might suggest that the original rock was an arkosic sediment, carrying locally variable amounts of quartz and K-feldspar. On the other hand, the body is seen to grade into amphibolite, not a granulite, along the strike to the east; and it is evident in any case that there has been an increase in silica during the metasomatism. The albitites are all surrounded by amphibolites, and were most probably formed from this rock.

The origin of the rutile, pyrite, tourmaline, and corundum in different parts of the kragerøite body must also be explained. Pyrite and tourmaline, containing relatively volatile constituents, are common in ore deposits and other residual products of igneous differentiation. The tourmaline of the small Lindvikskollen albitite body may be directly referred to schorl-bearing pegmatite only a few meters away; the Mg-rich variety in the contact zone is probably only a reaction product of this with the ferromagnesian minerals of the amphibolite.

Rutile is found abundantly in the other gabbro differentiates, the scapolite and apatite veins. Its peculiar association with albite in the kragerøite may be mere chance, but it bears a close resemblance to the disseminations of rutile in pre-Cambrian andesine anorthosite near Roseland, Virginia (Ross, 28). Apatite is here also closely associated with the rutile mineralization. The Roseland anorthosite body is much larger than the kragerøite (13 miles long, 22 square miles in area) and was evidently formed at a high temperature, as indicated by the high degree of solid solution in its feldspar (Ab 51, An 24, Or 25). Ross concludes that the major Ti content was introduced by pneumatolytic TiF_4 «after the granulation and consolidation of the anorthosite and [is] absent in the primary uncrushed feldspar. The titanium minerals are evidently the result of replacement and not of magmatic segregation or of pyrogenic processes» (p. 1). The Kragerø rutile deposits show no evidences of brecciation or granulation, but on the other hand they have most probably been metamorphosed and recrystallized after the introduction of the rutile. As a result, no definite conclusions can be reached as to the precise mode of emplacement of the rutile. Two points are of especial significance in this regard, however: 1. the rutile, aside from the low-concentration dissemination throughout the body, is concentrated in «schlieren» near and parallel to the north contact, which has been faulted; and 2. the Kragerø occurrence bears striking similarities to the Roseland deposits. It would not then seem unwarranted to propose for the Kragerø rutile deposits an origin similar to that proposed by Ross for the Virginia deposits after long and careful study of unmetamorphosed material.

The corundum which appears in two widely separated places but both in the kragerøite body poses another problem. If the kragerøite is considered magmatic, the magma would have had to assimilate a very highly aluminous sediment locally to result in a corundum-bearing rock, when the normal kragerøite contains some quartz. The presence of other «impurities», biotite and tourmaline, perhaps supports this hypothesis. If the kragerøite is metasomatic, the explanation is simpler if no more reasonable; if less silica were available locally during the metasomatism, the reaction might have progressed thus:

$$Na_2O + 2SiO_2 + \underset{\text{An}}{2CaAl_2Si_2O_8} \rightarrow \underset{\text{Ab}}{2NaAlSi_3O_8} + \underset{\text{Cor.}}{Al_2O_3} + CaO.$$

The textural evidence is confusing; the corundum is localized in the secondarily recrystallized areas of the kragerøite (see p.). Also, no transition zone to normal kragerøite has been found, containing aluminum silicates, which would be expected in any case. The origin of the corundum in this rock remains uncertain.

The large microcline pegmatites of the present area are notable for their abundance of rare-earth minerals and their complex history. The pegmatites are everywhere seen to be younger than their country rocks, whether amphibolite or albitite. The minerals at their contacts are often found to be oriented perpendicular to the contact, reminiscent of comb quartz in an open-fissure ore deposit. Harald Bjørlykke, who has studied the South Norwegian pegmatites exhaustively, contends «that the Norwegian granite pegmatites carrying rare elements have been formed as follows: after the injection of the younger pre-Cambrian granites, the residual granite magma, enriched in volatiles and rare elements, was intruded along cracks in the surrounding rocks. The temperature, however, was still high enough for the magma to remain in a liquid condition in these rocks for a long time. Through orogenic movements the magma was kneaded into the surrounding rock, part of it forming smaller or larger bodies without connection with other pegmatite material. During this time the initial crystallization stage was reached, the early mineral phases thereby becoming subjected to mechanical deformation as previously described, the adjacent rock at the same time developing a schistosity parallel to the pegmatite bodies . . . Some granite pegmatites were subsequently influenced by solutions and gases following cracks in the already congealed magmatic pegmatite, thus forming deposits of hydrothermal-pneumatolytic origin (cleavelandite, quartz, etc.), which are not of course in equilibrium with the magmatic minerals.» (10, p. 244). The Levang granite, a large stock just to the south across Kilsfjord from the present area, was studied by Brit Hofseth (12). It contains considerable oligoclase, and is a reasonable source for the pegmatite magmas of the Kragerø peninsula.

Jens Bugge concludes that a great deal of granitization has taken place in the Kongsberg-Bamle formation, but that «In cases where it is possible to show that an enrichment of rare earths in proportion to the granites has taken place, it is reasonable to suppose that [the pegmatites] belong to the [residual melts of palingenic granites] type, as there seems to be relatively little rare minerals in the metatectic rocks» (18, p. 127).

The structural and textural evidence cited above seems to support Bjørlykke's explanation. The Kragerø pegmatites fit admirably into the scheme of successive stages of mineralization set up by Fersman (as reported in TURNER and VERHOOGEN, 32, p. 332). Seven out of Fersman's ten types of pegmatite mineralization, grouped into pegmatitic, pneumatolytic, and hydrothermal stages with decreasing temperature, are represented in the Lindvikskollen—Kalstad body, for instance. According to this scheme, the rare earth minerals and related heavy-element minerals crystallize in the early, pegmatitic stage (roughly 800 to 600° C); in the following pneumatolytic stage (roughly 600 to 400° C), tourmaline and muscovite are formed, and later on, albite (cleavelandite) replaces microcline. In the lowest temperature, hydrothermal stage (roughly 400 to 100° C), carbonates, sulfides, and finally kaolin are formed.

Conclusions.

The Kongsberg-Bamle formation in the Kragerø region had a complex history during the pre-Cambrian era. Sediments of widely varying types (sandstones, arkoses, aluminous shales, etc.), intermixed with basalt lavas, were laid down in a sedimentary basin and intruded by small gabbroic stocks and sills and plugs before or during the Svecofennide (?) revolution. Mobile differentiates of these gabbroic magmas autometamorphosed parts of the gabbros to scapolite-hornblende rock, penetrated the surrounding rocks and the gabbros themselves, and produced scapolite-hornblende veins, apatite-rutile veins, and dikes and oddly-shaped bodies of albitite. The available evidence indicates a metasomatic origin for most if not all of the albitite bodies, mainly on the basis of the unlikelihood of residual magmas of the required composition.

The sediments with their gabbro intrusions were broadly folded and subjected to the P, T conditions of the high amphibolite facies (sillimanite zone), during which the sediments were transformed into schists, quartzites, and gneisses, and the outer portions of the gabbros were altered to amphibolites, through the diffusion inward of water from the surrounding sediments. The foliation developed during the metamorphism bends around the tough, resistant cores of these gabbros.

During the later stages of orogeny, the Levang granite was intruded into the metamorphic rocks immediately to the south of the map area, and pegmatitic residual magmas developed. These were intruded, while completely liquid, into the country rocks, and crystallized while cooling slowly, to form the pegmatites of the Kragerø Peninsula. Several successive stages or waves of mineralization in the pegmatite are evident, the most striking of which is the replacement of earlier microcline perthite by cleavelandite, as in the Tangen pegmatite.

At some unknown stage after the peak of metamorphism, (perhaps at the time of the granite intrusion) the rocks became at least partially adjusted to an environment of slightly lower temperature or slightly more water, or both, within the stability range of muscovite but still in the sillimanite zone.

At some later time the rocks were again subjected to strong shearing stresses, which produced faulting and brecciation locally in the now rigid rocks. Iron oxides, in a gangue of quartz, calcite, and albite, were deposited along a fissure extending roughly east-west across the map area.

The last two or three events were probably associated with uplift of the area into a mountain chain, and erosion, including Pleistocene glaciation, has been the only agency in evidence since that time.

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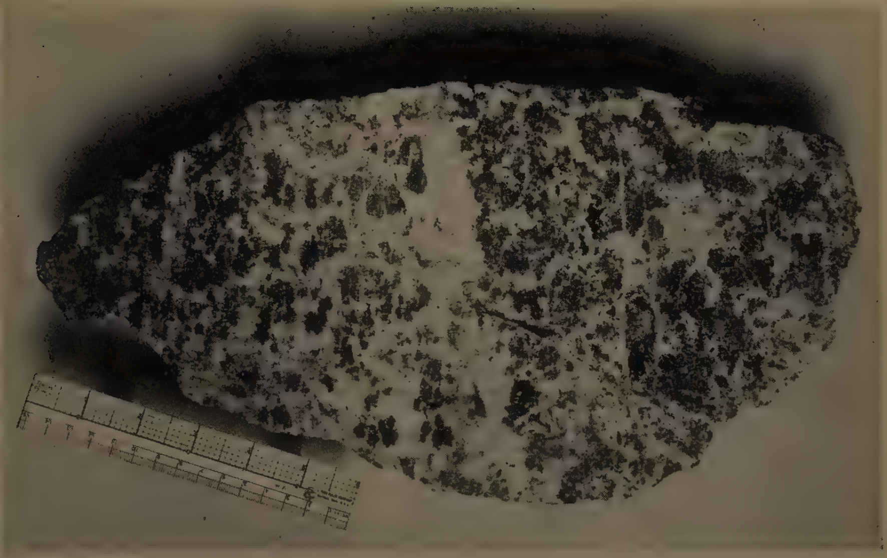
PLATE I

PLATE I.

a. Corundum-bearing krager&oslash;ite, Lindvikskollen. b. Corundum-bearing krager&oslash;ite, Lindvikskollen. High relief corundum, medium relief muscovite, low relief albite, dark biotite. Plane light × 116.



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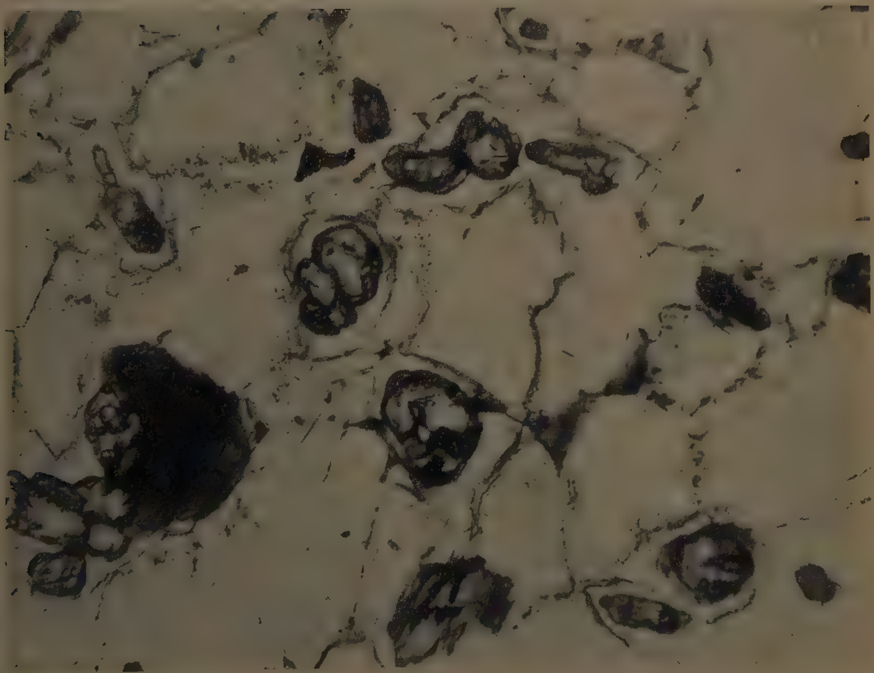

I b

CONTRIBUTION TO THE GEOCHEMISTRY OF GRANITE PEGMATITE

BY

IVAR OFTEDAL

Abstract. The behaviour of certain elements during the replacement of amazonite pegmatite by cleavelandite pegmatite is considered. In conclusion some remarks on the enrichment («capture») principle are added.

The following is based mainly on two occurrences of amazonite and cleavelandite pegmatite in Southern Norway (Tørdal), which have been briefly described some years ago (1). They are located some 2 km apart within and near the boundary of an area of gabbro and crystalline schists surrounded by the so called Telemark Granite. The pegmatites obviously are genetically connected with this granite. The cleavelandite pegmatite occurs within pre-existing amazonite pegmatite, and has clearly been formed by metasomatic replacement processes. In the one locality (Skarsfjell) these processes have only just started: the cleavelandite pegmatite forms irregular veins in the still quite predominating amazonite pegmatite. In the other locality (Høydalen) the amazonite pegmatite has nearly disappeared, being preserved in scattered lumps only, within a predominating mass of cleavelandite pegmatite. Chemical and mineralogical differences between the cleavelandite pegmatites of the two localities may be due to these differences in the stage of development.

Apart from the main constituents the amazonite (in both localities) contains the following elements in spectrochemically significant concentrations: Rb, Cs, Tl, Pb, Sr, Ga, and traces of Mg, Fe, Mn.

Barium is absent, or nearly so. This is in accordance with the «capture» rule given by V.M. Goldschmidt. The Ba ion has a higher charge than the K ion, and is also somewhat smaller in size: therefore it should be captured in alkali feldspars belonging to earlier stages of development. In the present case this process has worked very efficiently, having removed the Ba nearly completely before the formation of the pegmatite. The microcline of the nearby Telemark Granite exhibits quite normal contents of Ba, some hundred parts per million.

Strontium behaves in a similar way, but the difference between the granite microcline and the amazonite is here somewhat less marked. The Sr content of the granite microcline is hardly ten times that of the amazonite. It is probable that the Sr in the amazonite mainly replaces K, but part of it may possibly replace Na (or Ca) in the perthite lamellae. Facilities for very accurate trace element determination have not been at my disposal; I hope to be able to improve the measurements later. But assuming the age of the pegmatites to be something like 1 000 million years, my present approximate values for Rb and Sr may very well indicate that the Sr in the amazonite is mainly radiogenic. L. H. Ahrens (2) has found values between 40 and 80 % for the ratio Sr^{87}/Sr in amazonite. The ratio will depend on the extent to which «ordinary» Sr has been removed before the formation of the amazonite. It is probable that Sr has been no less effectively removed than Ba.

Lead and *thallium* occur in the Tørdal amazonites in concentrations which approach 1 000 p.p.m. The present writer has examined spectrochemically a large number of alkali feldspar samples from granites and granite pegmatites, and published part of the results(3). He never elsewhere came across Pb (or Tl) concentrations approaching those of the Tørdal amazonites. The feldspars containing appreciable amounts of Pb were all microclines, but the contents are highly variable. In some granite bodies in gneiss areas the Pb content may exceed 100 p.p.m., in others it may be ten times less. The same is true of archaean pegmatite bodies, but here it is possible to make a distinction between two types of different geological occurrence, as will be shown below. It appears that Pb enters preferentially into «late» microclines; in high temperature alkali feldspars (orthoclase) it does not seem to occur at all. This is contrary to what was expected by V. M. Goldschmidt (4, p. 399), and in fact it can hardly be for purely crystal chemical reasons. In spite of the similar ionic radii and charges, Sr and Pb behave quite differently during the formation of granitic rocks. Sr strictly follows the rule of «early capture», Pb does not, at least as shown by numerous data from Southern Norway. Of course the chemical characters of Sr and Pb are different. The maximum observed Pb content increases very markedly along the series: orthoclase from granite (below 5 p.p.m.) — microcline from granite (over 100 p.p.m.) — microcline from granite pegmatite (about 1 000 p.p.m.), but on the other hand these maximum values are approached in a few cases only. It appears that in many cases Pb has not been available, or very scarce. Most striking is the fact that the Pb content of microcline may vary by a factor of 100 or more in different pegmatite bodies. This may be partly due to the strongly chalcophil character of Pb, which might sometimes lead to a concentration of Pb in galena outside the examined bodies. But the Pb-poor and the Pb-rich pegmatites in general seem to be genetically different. The former mostly are integrating parts of gneiss areas, probably formed by granitisation more or less in situ, the latter are clearly connected with large granite bodies and intrusive in adjacent rocks, so that a concentration of Pb (and other rarer elements) is to be expected. I think that generally the pegmatites rich in «rare» elements must have gathered these from larger parent granite bodies, while pegmatites of the former type must generally be barren. It may be pointed out in this connection that in Tørdal the Pb content has increased by a factor of about 10 from the microcline of the Telemark Granite to the amazonite of the pegmatites.

The process by which amazonite pegmatite has been replaced by cleavelandite pegmatite must have required addition (and also subtraction) of various materials. The amazonite pegmatite itself does not seem to contain anything but amazonite perthite, quartz, and perhaps some mica. The main constituents of the cleavelandite pegmatite are cleavelandite, quartz, various Li-rich micas, muscovite, topaz, beryls, cassiterite, fluorite. Some minerals containing Ta, Nb, Ce, Zr, etc. occur in quite small quantities.

Because of the large quantities of cleavelandite observed at Høydalen, it is obvious that much *sodium* must have been added; the perthite lamellae of the amazonite would by no means offer sufficient material. The cleavelandite may possible originate through decomposition and redeposition of ordinary (graphic) albite pegmatite which is observed to occur as boundary zones between the amazonite pegmatite and the country rock.

On the other hand much *potassium* must have disappeared from the pegmatite, as the quantities of mica minerals are certainly not large enough to account for the K that must have been present in the decomposed amazonite.

The *rubidium* and *cesium* from the decomposed amazonite, however, may have been transferred nearly quantitatively to the micas of the cleavelandite pegmatite, as these are on the average considerably richer in Rb and Cs than the amazonite. Small quantities of Rb and Cs are also found in the beryls. Thus it is probable that the Rb and Cs quantities present have not been notably influenced by the replacement process.

All the micas contain *strontium* in small and nearly equal concentrations, similar to those in the amazonite. Of the other minerals only Rb-rich beryls contain Sr in detectable quantities. According to Ahrens (2) the Sr in micas (especially lepidolite) is almost exclusively Sr^{87}. Also, V. M. Goldschmidt has pointed out (4, p. 246) that micas do not seem to be able to incorporate Sr by ordinary capture. Even without a knowledge of these statements I should have supposed that the Sr in the Tørdal micas is mainly radiogenic. The Sr is always associated with much larger quantities of Rb; it does not occur in the cleavelandite; and finally, Ba is not detectable in the micas. A very accurate determination of the Rb/Sr ratio in these micas should thus give a good value for the age of the deposits. (There is obviously no geologically significant age difference between the amazonite pegmatite and the cleavelandite pegmatite. Therefore there was probably no Sr^{87} present in the amazonite at the time of replacement.)

The *lead* contents of the micas are on the average lower than those of the amazonite, and in other minerals of the cleavelandite pegmatite only insignificant amounts of Pb have been found. Thus no Pb seems to have been introduced by the replacement process, on the contrary, some Pb probably has been carried away.

Thallium behaves very much like Pb. Relatively very large quantities of Tl must have been supplied from the decomposing amazonite. In the cleavelandite pegmatite Tl is found in the micas only, mostly in much lower concentrations than in the amazonite. The cleavelandite pegmatite thus contains only a small fraction of the Tl originally present. The surplus Tl may have been fixed somewhere in the environs, probably at higher levels now removed by denudation, perhaps with Pb in galena. This is to be expected because of the partly chalcophil nature of Tl, and in fact nearly all of the chalcophil Tl is found in galenas.

As is well known, Rb^{1+} and Tl^{1+} are crystal chemically so closely related that they never seem to part in minerals(5). This is well demonstrated in the Tørdal pegmatites. But it must be remarked that the ratio Tl/Rb is 5 to 10 times higher in the amazonite than in the micas, not counting some rare muscovites which are exceptionally rich in Tl. The replacement process has clearly been able to separate Rb and Tl to some extent. This does not seem to be due to the difference in crystal structure between feldspar and mica, since the rare muscovite just mentioned exhibits about the same Tl/Rb ratio as the amazonite. A possible explanation might be that Rb is purely lithophil, Tl only partly so.

The *gallium* content of the amazonite seems to have been preserved fairly unchanged in the cleavelandite pegmatite. As usual, Ga is found in all the Al-rich minerals. The average Ga content of these is fairly high, probably in excess of 100 p.p.m., but there are some notable deviations. It is not always possible to establish age relations between the minerals of cleavelandite pegmatite, but in some cases this could be done with certainty. Thus a white mica had grown in parallel position on a dark mica as a core. The white (younger) mica here turned out to be much poorer in Ga than the dark one. Also the very abundant Li-micas («lepidolites»), which apparently belong to the very latest minerals, are exceptionally poor in Ga. This does not agree with the camouflage rule of V.M. Goldschmidt. But I think it indicates that Ga was scarce during the latest stages of mineral formation. Very striking are the low Ga contents of topaz as compared with feldspars, beryls, and some of the micas. Topaz generally appears to be one of the earliest minerals of the cleavelandite pegmatite. Low contents of Ga seems to be a specific property of topaz in general. I have examined topaz from a number of different deposits, and never found higher Ga contents than about 10 p.p.m. (V.M. Goldschmidt (4, p. 324) has quoted a similar figure for Ga in topaz, but this came from a deposit where also the micas were poor in Ga.). It is obvious that this peculiarity is due to crystal chemical properties, but it is hardly possible at present to give a more definite explanation. Another peculiarity of topaz is, as well known, that it contains much more *germanium* than any other of the more common minerals. In fact, the only pegmatite minerals in which I have myself found Ge, are topaz and spessartite, and the higher concentration was always in the topaz. And I never came across a topaz which did not contain considerable quantities of Ge, mostly several 100 p.p.m. Observations thus indicate that topaz tends to avoid Ga and collect Ge. These tendencies may be interconnected. Tentatively I would suggest that in this case Ge may replace Al (not Si), and that this in some way may hinder further replacement of Al by Ga. (The electric neutrality might be re-established e. g. by letting a little O replace F.). As to the immediate source of the Ge, it may be the spessartite which is observed to occur in the primary pegmatite (in the albite pegmatite zones referred to above), and which is sometimes found as partly decomposed nodules embedded in the cleavelandite pegmatite.

Elements which have clearly been supplied during the replacement process are F, Li, Sn, Be, Sc. Other elements, like Y and rare earths, Nb, Ta, Ti, Zr, P, occur in very small quantities, and may have been present in the primary pegmatite. This certainly applies to *yttrium* and *rare earths*, since gadolinite occurs quite abundantly in the zones of albite pegmatite and is found partly decomposed in the cleavelandite pegmatite. Some *beryllium* is also accounted for by the decomposition of gadolinite, but this does not seem to be sufficient for the formation of the abundant giant crystals of beryl observed in the cleavelandite pegmatite.

Fluorine has been very abundant, as shown by the large quantities of topaz, micas, and fluorite.

Lithium is found in mica minerals, especially in the very abundant varieties, which contain 3 to 5 % Li_2O, and further in colourless to pink beryls, which are also fairly rich in Cs. On the whole Li appears to have been concentrated especially in the very latest minerals of the cleavelandite pegmatite.

Most of the *tin* is found in cassiterite. But Sn is also a characteristic constituent of all the mica varieties. In some micas the Sn content exceeds 100 p.p.m., in others it is hardly more than 10 p.p.m In some cases it can be shown quite definitely that the low Sn contents are characteristic of late micas, the high contents of earlier ones. Because of its ionic radius Sn must be supposed to replace Fe (or Mg or Li) in the mica structure. As this is a very pronounced case of «capture» the observed distribution of Sn between early and late micas is in accordance with Goldschmidt's rule.

Scandium has been found in the cassiterite, in some micas, and in some beryls. The concentrations in mica may reach values exceeding 1 000 p. p. m. The high Sc contents are found in micas which apparently belong to the earliest minerals of the cleavelandite pegmatite. In some cases it can be stated quite definitely that the Sc content decreased by a factor of at least 10 during the zonal growth of such a mica crystal. Also, the very Li-rich micas («lepidolites») and some other presumably very late micas did not show any Sc at all. This deficiency in Sc in the latest micas is probably not to be explained crystal chemically. It is much more probable that there was no Sc left at the latest stages of mineral formation. This is confirmed also by observations on the beryls. Sc was found in the earliest (yellow, partly corroded) beryls only, not in the later (bluish and pink) ones. Sc, like Sn, must be supposed to replace Fe in the micas (Mg is very scarce in all of them), and this would again be a case of capture. The above data might be interpreted as being in support of the capture rule. But it has been shown earlier (6) that there is really a very marked increase in the Sc content of biotite along the series: magmatic rocks — microcline granite and gneiss — granite pegmatite. The decrease observed in the Tørdal pegmatites is at the very end of the series, and is therefore given the above interpretation. Thus the behaviour of Sc in mica minerals is not in agreement with the capture rule.

In conclusion I might make some remarks on the capture principle in general. It has been argued that capture should not be any more probable than other kinds of diadochy, because capture of one element in a crystal structure must generally be coupled with admission of an other. D. M. Shaw (7) in particular has discussed this question in some detail, and arrives at the conclusion that the «enrichment principle» of V. M. Goldschmidt (including the capture rule) is not valid: it is not possible to predict the distribution of a trace element between «early» and «late» crystals from its properties alone.

It is certainly true that the capture principle has no general validity, or at least that it does not operate alone. Every worker on trace elements in minerals will know this from his own experience; he frequently comes across «surprises». Thus also the above observational data in several cases clearly contradict the capture rule. V. M. Goldschmidt himself was fully aware of such exceptions from his rule, as I know from verbal discussions with him, but I think he never gave up the belief that the capture rule has a real background. The capture rule may be taken in a wider and a more restricted sense. We may consider the distribution of an element between early and late mineral associations, e. g. between early and late differentiates of a magmatic rock series, and we may consider the distribution between early and late fractions of one and the same mineral, or between early and late members of a series of isomorphous mixed crystals. These distributions may be quite different. Thus Sc is found mainly in pyroxenes and amphiboles of basic and intermediate rocks. In late differentiates (granites etc.) pyroxene and amphibole have usually disappeared, and the only ferromagnesian mineral is biotite, which is much poorer in Sc. Late differentiates thus contain only a small fraction of the Sc which was present in the earlier ones. On the other hand the biotites of basic and intermediate rocks are even poorer in Sc than those of the acid ones, even in equilibrium with very Sc-rich pyroxenes or amphiboles (6). It is obvious that the nature of the crystal is at least as important in determining the possibilities of diadochy as the properties of the ions, and it is clearly useless to compare the content of an element in an early mineral with that in a fundamentally different late mineral in order to get an understanding of the enrichment mechanism. (I also think that the system with the end members A and B and the minimum melting compound A_mB_n, considered by Shaw (l. c. Fig. 5), is not really relevant, as the two series of solid solutions are A_mB_n enriched in A, and A_mB_n enriched in B, that is: the «trace element» is not the same in the two series.)

I think that a profitable discussion may be possible only when the enrichment principle is taken in the restricted sense, i. e. as applied to genetically connected minerals belonging to the same species or the same isomorphous series. Even so there is no doubt that Shaw is right in his criticism of the principle. The above statement that Sc is relatively enriched in late (low temperature) biotites is one instance that clearly contradicts it (Sc^{3+} and Fe^{2+} are equal in size, but Sc has the higher charge). On the other hand, the striking success of the capture principle in many important cases requires an explanation. If a crystal containing a trace element may be considered as a mixed crystal between two isomorphous end members, a case in which the «restricted» enrichment principle might be applied, then Shaw points out that the higher melting end member must be enriched in the earlier fractions. Apparent agreement with the enrichment principle would then mean that the higher melting member by chance contained the smaller cation. In simple systems I do not think this is merely by chance. Of two isomorphous crystals which have all elements but one in common, the one with the strongest bonds will most probably have the higher melting point.

Cases where ions of different charges are exchanged are not so easily explained. The exchange of Ca^{2+} for Na^{1+} in the plagioclase series is in agreement with the capture rule, but the «coupled» exchange of Al^{3+} for Si^{4+} is not. Obviously the tendency to capture Ca is here stronger than the resistance against the admission of Al. At first sight this is unexpected, since of course the changes in the charges exactly compensate each other, and in addition Al^{3+} is considerably larger than Si^{4+}. But the fact remains that in this coupled diadochy the capture process strengthens the bonds by a factor of 2, while the admission process weakens the bonds by a factor of 4/3 only. Thus the bonds inside the tetrahedral network are relatively less altered than the bonds outside it. Taking this view, Ca is actually more strongly «attracted» by the albite structure than Al is «repulsed». This would explain why the capture process seems to operate in the plagioclase series and in other similar cases, e. g. in alkali feldspar containing Sr, Ba, Pb, and probably also in micas containing Ba and Pb.

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SMALL SCALE TECTONICS

in a South Norwegian Gneiss Complex

By

Ivar Oftedal

With 2 plates.

The plagioclase gneiss complex on the coast off Lillesand is remarkably uniform both in composition and in large scale structure. Along the shore towards the open sea the rocks are excellently exposed, so that every structural detail can be studied.

Plagioclase gneiss accounts for about 95 % of the rock surface, on the average. The main constituents of the gneiss are acid andesine (about An_{33}) and quartz. Subordinate but varying contents of biotite make the colour shift somewhat in shades of grey. Small quantities of epidote are usually present. Accessories are mostly scarce. Apart from a subparallel arrangement of the mica flakes the texture is perfectly granoblastic. The grain size is somewhat variable, but usually it is confined within the limits 1 and 2 mm. As will be shown below, the gneiss may be divided into roughly 2 types, mainly on tectonical grounds. On the average the one type — the more «competent» one — is more coarse grained and somewhat darker than the other. Both types are of great importance.

The remaining 5 %, roughly, of the area are made up of amphibolite, «micaschist» (really very biotite-rich gneiss), granite pegmatite, and vein quartz, in bodies of varying size and shape.

The amphibolite consists of an ordinary green hornblende, andesine (about An_{43}), and common accessories. At the contact towards granite pegmatite amphibolite may contain abundant biotite, epidote (about 30 % Fe-component), and sphene. The «micaschist», which is also extremely rich in epidote and sphene, may represent a further development of this process: the alteration of amphibolite through potassium metasomatism. The amphibolite is mostly fine grained, grain size 1 mm or less. The central parts of thicker bodies are massive with nearly equidimensional hornblende grains. Border zones and small bands etc. are schistose.

Granite pegmatite bodies are of highly variable shape, size, and tectonic setting. The grain size is approximately proportional to the thickness of the body and varies between a fraction of a mm and about 10 cm. The pegmatites are obviously of a metasomatic origin. Both amphibolite and pegmatite have appeared at various stages of development of the complex. The quartz veins are the youngest rocks in the area.

It is evident from the above statements that the complex is in high epidote-amphibolite or low amphibolite facies, according to the facies definition adopted (epidote in equilibrium with plagioclase up to about An_{40}). The rocks are all very fresh and exhibit very few traces of subsequent alterations. The present facies may be assumed to represent the conditions during the main phase of crystallization.

The large scale structure of the area can be closely represented by a schistosity plane striking N 38° E and dipping E 38° S $45 \pm 10°$. In the field the gneiss bands may appear from several meters down to a few millimeters thick. They are mostly straight for long distances. In hand specimen also the thicker bands usually exhibit a fine lamellar schistosity. In certain bands of the coarse grained type the schistosity may be absent or highly irregular. On the whole the schistosity is much more prominent in the fine grained gneiss bands than in the coarser ones. (Fig. 7).

Examples of small scale tectonics. Almost all the rocks show very distinct signs of internal movement in the main schistosity plane, and nearly all rock units have obviously been highly flattened (Figs. 1,2). As the original shapes of the various bodies are unknown, nothing definite can, however, be said about the amount of flattening. Some of the gneiss units, and possibly all of them, may gave formed from a medium which was in a state of continuous flow; in this case their original shapes may not have differed appreciably from the present platy and lenticular ones.

Some rock types, notably fine grained gneisses and still more the locally occurring «micaschist», show much stronger signs of flow than all the others. They behave in a very incompetent manner as compared with the coarser gneiss types, the amphibolites and the pegmatites. In many cases it can be seen that the competent rocks have been broken into larger and smaller pieces partly or wholly surrounded by fine gneiss or «micaschist». The schistosity surfaces of the latter then bend around corners and other irregularities of the fragment boundaries, giving boudinage-like structures or even breccias on larger and smaller scales (Figs. 5, 8, 9). Such observations demonstrate convincingly that the fine gneiss was some time highly mobile, and that it appeared later than the more competent rocks. Most of the fine gneiss, however, occurs in the regular way as straight bands alternating with bands of the other rocks (Fig. 7). Therefore it is assumed that fracture of the competent rocks most frequently occurred along already existing schistosity planes, and that adjacent competent plates afterwards moved relative to each other. The fine gneiss may have been introduced between the fragments from below, by plastic flow. However, I think it is more probable, since the fine and coarse gneiss types are very similar in composition, that mylonitic zones were formed in connection with the fracturing, and that the mylonite recrystallized afterwards during plastic flow movement, giving the fine grained and fine lamellar gneiss types. Recrystallization should take place preferably in such mylonitic zones, both because of the simultaneous movement and because of the small grain size. The competent plates and fragments themselves apparently were not notably deformed or recrystallized during this process. There are reasons to believe that the stress causing the flow was comparatively very slight. It has been able in some cases to fold and otherwise deform small bands and dikes embedded in incompetent rocks (Figs. 3, 4, 6). But it has not been able to break large single microcline crystals in immediate contact with flowing gneiss (Fig. 11).

It appears that the competent rocks once formed an «old complex» which had reached a stage of relative rest and a high degree of rigidity, when renewed activity on the same lines as before caused the fine gneiss to form and flow, and new granite pegmatites to appear.

The metasomatic origin of these pegmatites is highly evident. Remnants of gneiss are frequently seen within the larger bodies, which in addition may exhibit very irregular boundaries depending on the relative «solubility» of the various gneiss bands (Fig. 13). In thin section it can be seen how the pegmatite formation begins:

small microcline individuals accompanied by myrmekite appear thinly scattered in the plagioclase gneiss. As this incipient pegmatite formation is often observed along narrow gneiss bands, it is assumed that potassium metasomatism and plastic flow took place simultaneously. The potassium metasomatism must have continued until the renewed movements had nearly stopped and the complex attained its present structure. Some pegmatite bodies, especially veins and small dikes, show more or less folded, squeezed or flattened shapes (Fig. 6). But some relatively large ones, up to many square meters in size, form irregular patches («petroblasts») in the gneiss, completely massive and undeformed (Figs. 13, 14). These latest pegmatite bodies are not visibly influenced by the stress at all, even if the surrounding gneiss itself still shows weak signs of plastic flow (Fig. 14). The central parts of these pegmatites may contain microcline crystals up to 10 cm in size. But a narrow border zone is still fine grained, evidently because here the formation of new growing microcline crystals was still going on.

About at this stage the whole area was traversed by a set of vertical joints, most of them perpendicular to the main schistosity plane. These joints are now highly conspicuous features in the landscape. They are doubtless due to a continued action of the stress which formed the gneiss structures, now acting on nearly rigid rocks. Complete rigidity had not been reached, though, for it is sometimes observed that the rocks have been slightly deformed after the formation of the joints, e. g. more compressed on one side of the joint than on the other (Fig. 12). The deformation is of the same order of magnitude as that which occurred after the formation of the latest pegmatites; therefore it is assumed that these and the joints were formed about at the same time. The mechanical properties of the gneisses at this stage must have been such that they could yield slowly to a long lasting stress but at the same time develop internal tensions strong enough to produce sudden cracks. The joints have sometimes been opened and filled with vein quartz. Similar quartz fillings are also found between pegmatite boudins (Fig. 10) and between more irregular rock fragments.

Typical boudinage structures seem to belong to late stages of development, i. e. to stages (or localities) where the relative movements were very slow. Rapid flow of incompetent rocks along competent bands would presumably take most boudins far apart. It might even rotate the fragments and produce breccia structures like those referred to above. In any case the incompetent rock would fill completely the spaces between the fragments, not just bend slightly towards the space between boudins, leaving most of it open for the usual quartz filling (Fig. 10).

Boudinage and similar structures may form in various mineral facies. The competent bands usually consist of amphibolite (or equivalent gabbroic rocks) and granite pegmatite. In the present case the (chemically uniform) plagioclase gneiss itself occurs in both competent and incompetent bands, and as both fragments and matrix in breccias. This would hardly be possible in higher facies, where all of the gneiss would presumably be rapidly mobilized and recrystallized.

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august 1956.

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PLATE I.

Fig. 1. View in the strike direction, towards NE. Gneiss with amphibolite and pegmatite (light) bands.

Fig. 2. Vertical rock wall some 10 m high, perpendicular to the schistosity. View towards NE. Gneiss with lenticular amphibolite body.

Fig. 3. Amphibolite band, 10 to 20 cm thick, folded in fine grained gneiss.

Fig. 4. Band of fine grained gneiss, a few cm thick, folded and highly distorted in biotite-rich gneiss.

Fig. 5. Amphibolite fragments in a matrix of fine grained gneiss.

Fig. 6. Small pegmatite dike folded in fine grained gneiss. Horizontal rock surface. Area about 40 by 30 cm.

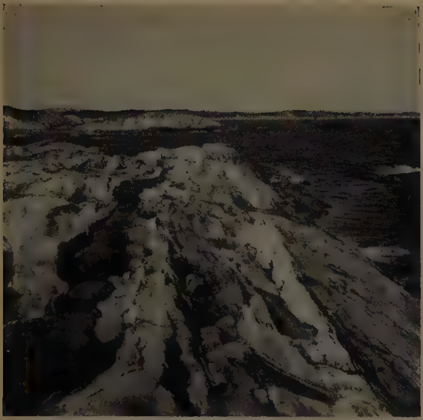


Fig. 1

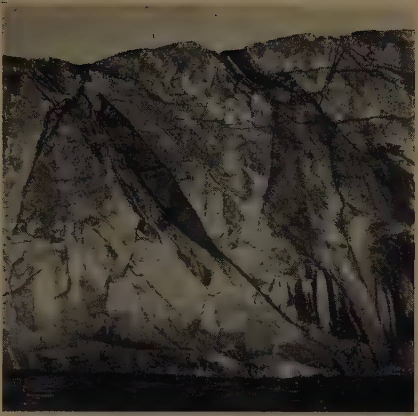


Fig. 2

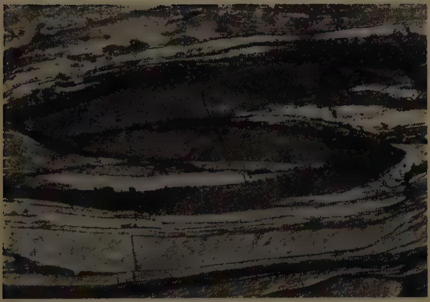


Fig. 3

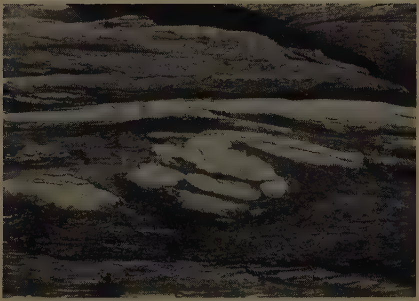


Fig. 4

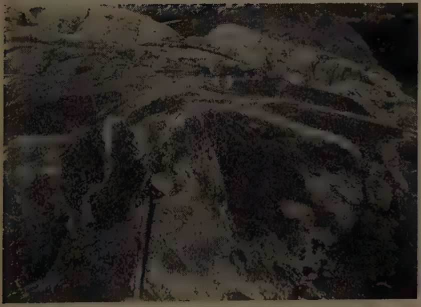


Fig. 5

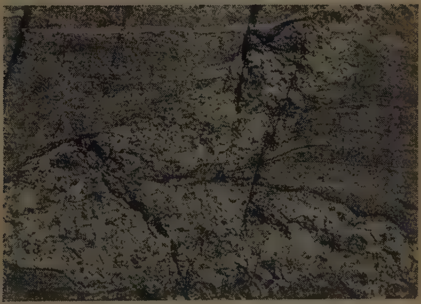


Fig. 6

PLATE II.

Fig. 7. Broad bands of coarser (left) and finer gneiss in contact. A few m^2 of the rock surface.

Fig. 8. Lenticular fragment, some 2 m long, of coarser gneiss in finer gneiss.

Fig. 9. Lenticular fragments of amphibolite separated by veins of fine grained gneiss. The lower very regular lens is about ½ m long.

Fig. 10. Boudinage structure with quartz filling in a granite pegmatite band, about ½ m thick.

Fig. 11. Pegmatite «knot» with angular microcline crystals (left) in «flowing» gneiss. Nearly horizontal rock surface. Area about 40 by 30 cm.

Fig. 12. Unequal deformation of gneiss on the two sides of a joint. Horizontal surface. Area about 40 by 30 cm.

Fig. 13. Remains of partly consumed gneiss bands protruding into massive irregular pegmatite body. Upper right corner: large amphibolite body.

Fig. 14. Pegmatite body, about 1 m long, replacing gneiss. Most of the body is quartz, possibly younger vein quartz. Microcline occurs in a narrow border zone only.

All the photographs have been taken near the East end of the island of Justøy.

PLATE II

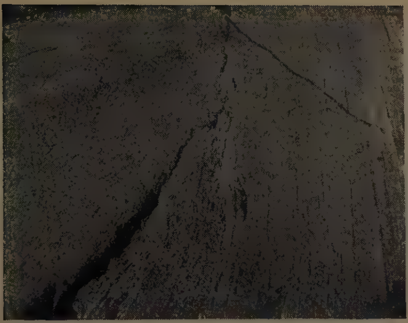


Fig. 7 ←

Fig. 8 →

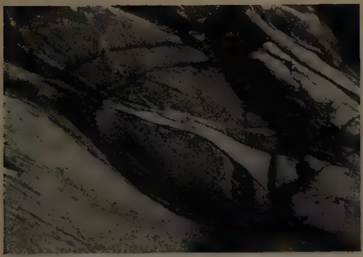
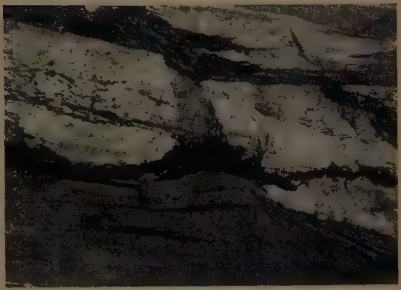


Fig. 9 ←

Fig. 10 →



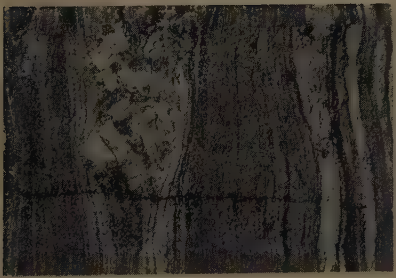
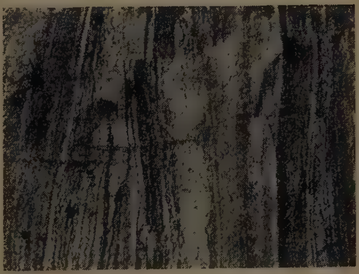


Fig. 11 ←

Fig. 12 →



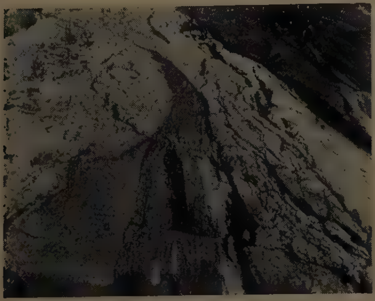
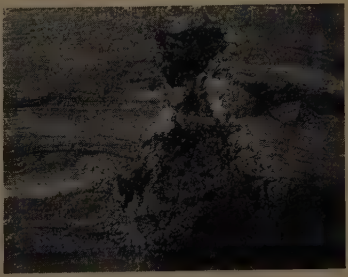


Fig. 13 ←

Fig. 14 →



NORSK GEOLOGISK TIDSSKRIFT 36

KALEDONSK TEKTONIKK I MIDT-NORGE

On the Caledonides of Central Norway.

AV

IVAR HERNES

INNHOLD

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Abstract. In the present paper the author offers an interpretation of the main stratigraphical and tectonical features of the Molde-Trondheim district, Central Norway. A system of W—SW folds is described, inclusive of the Trondhjemsfjord Syncline.

According to TH. VOGT (1954 a) the W—SW direction of the structure is further developed in a connection between the syncline of Hornelen and the Dombås district of the Trondhjem Region; and according to H. CARSTENS (1955) his investigations in the Trondhjemsled-Snåsa Syncline shows that the W—SW direction of the structure originated in early Caledonian times. The authors conclusion is that the Trondhjem Region continues straight into the Western Gneiss Area, and that the W—SW system of folds also presumably forms the main direction of the Caledonian mountain range in this district.

Forord.

Denne skisse over kaledonsk tektonikk i Midt-Norge bygger på mine undersøkelser i Møre og Romsdal, reiser i Trøndelag og litteraturstudier. Jeg har mottatt verdifull kritikk fra cand. real. HARALD CARSTENS, Trondheim.

Frøken ELLEN IRGENS har tegnet kart og profil.

Jeg vil takke for all hjelp.

Geologisk institutt, Universitetet i Bergen, februar 1956.

Innledning.

I flere interessante arbeider om kaledonidene i Skandinavia har Th. Vogt diskutert fjellkjedens tektonikk. I en diskusjon om den foldningsfase som av Vogt er kalt Svalbardfoldningen, fremhever Vogt det V—SV lige foldesystem, og påpeker samtidig den sannsynlige forbindelse mellom Trondhjemsfeltet og Vestlandets devonsynklinaler (1928, s. 113). Samme sted fremheves at dette foldesystem griper dypt inn i det gamle underlag, men det antas som helhet eller for en vesentlig del å være av yngre alder.

I sin tankevekkende trilogi (1954 a, 1954 b, 1954 c) fører Vogt ideen om en forbindelse mellom Trondhjemsfeltet og Vestlandets devonsynklinaler videre. I disse arbeider er det trukket en synklinal over fra Hornelens devon til Dombåsområdet i Trondhjemsfeltet. Denne synklinal går parallelt med den nordenforliggende Trondhjemsfjordsynklinal, som jeg vil ta som utgangspunkt i den følgende beskrivelse.

Nord for Trondhjemsfjordsynklinalen er det V—SV lige foldesystem meget markert, og spesielt hos Trondhjemsled—Snåsasynklinalen, som er den mest fremtredende synklinal i dette område. H. Carstens (1955) antar at denne synklinalen ble anlagt allerede i tidlig kaledonsk tid. Dette viser at det V—SV lige foldesystem begynte å gjøre seg gjeldende allerede tidlig under kaledonidenes dannelse.

Mine undersøkelser viser at det V—SV lige foldesystem i Midt-Norge antakelig er av en så gjennomgripende karakter, at det i området Det vestlige gneisområde—Trondhjemsfeltet danner den kaledonske fjellkjedes hovedretning.

Regional oversikt.

Trondhjemsfjordsynklinalen.

Th. Vogt (1954 a, s. 103) beskriver Trondhjemsfjordsynklinalens utbredelse. Den kan følges fra vest for Molde og øst—nord—østover, og består fra vest mot Trondheim av Molde-Tingvollsynklinalen (Hernes 1956 a), (Stangvik) — Surnadalssynklinalen (Hernes 1956b), Løkkenfeltet (C. W. Carstens 1951, se også H. Carstens 1954 med geologisk kart av C. W. CARSTENS) og Hølondafeltet (TH. VOGT 1945). VOGT har på sine kart (1954 a, fig. 1 og 1954 b, fig. 1) trukket Horgsynklinalen syd for Hølondafeltet inn i Trondhjemsfjordsynklinalen. Som det vil fremgå av den følgede beskrivelse vil synklinalen etter min oppfatning gå over Hölondafeltet, og således få et mere rettlinjet forløp.

Videre nord-østover fortsetter Trondhjemsfjordsynklinalen over Eknefeltet (A.E. TÖRNEBOHM 1896, se også TH. VOGT 1945, s. 503—506).

Et karakteristisk trekk ved Trondhjemsfjordsynklinalen er at den vider seg ut fra vest mot Hølonda, se fig. 2. Ved Molde er den isoklinal med akseplan som faller syd. Allerede ved Stangvik er synklinalen ganske vid med en meget flat ombøyning. Nederst i Surnadalen viser foldninger innen selve synklinalen en begynnende dannelse av synklinaler av 2. orden; et forhold som er meget markert lengere øst, innen Løkkenfeltet og Hølondafeltet.

Et annet karakteristisk trekk ved Trondhjemsfjordsynklinalen og de tilgrensende antiklinaler i Molde-Hølondaområdet er foldningsakser med stort sett østlig fall.

I Molde-Stangvikområdet går Trondhjemsfjordsynklinalen mot nord over i en antiklinal, hvis foldningsake har østlig fall. Som tidligere beskrevet er det ikke iakttatt trekk som tyder på en kulminasjon nord for Tingvoll (HERNES 1956 a, s. 4).

I Tingvoll-Stangvikområdet går Trondhjemsfjordsynklinalen mot syd også over i en antiklinal med foldningsakse med østlig fall. Videre kommer vi i dette område mot øst til stadig høyereliggende bergarter, fra homogene gneiser via Tingvollgruppen til Rørosgruppen. Etter mine rekognoserende undersøkelser syd for Molde-Tingvollsynklinalen, ser det ut til at antiklinalen fortsetter vestover, med foldningsakse med østlig fall, og at stadig dypereliggende bergarter sees i dagen mot vest. Det er således heller ikke syd for Tingvoll iakttatt trekk som tyder på en kulminasjon i dette området (GJELSVIK 1953, s. 73, s. 86).

La oss så se på selve Trondhjemsfjordsynklinalen. Jeg har studert synklinalens foldningsakse nærmere mellom Molde og nedre del av Surnadal. Fallet veksler her omkring horisontalt, til dels sees vestlig, og til dels østlig fall. Ser vi på synklinalens trondhjemsskifre er det tydelig at vi mellom Molde og Stangvik har et kulminasjonsområde,

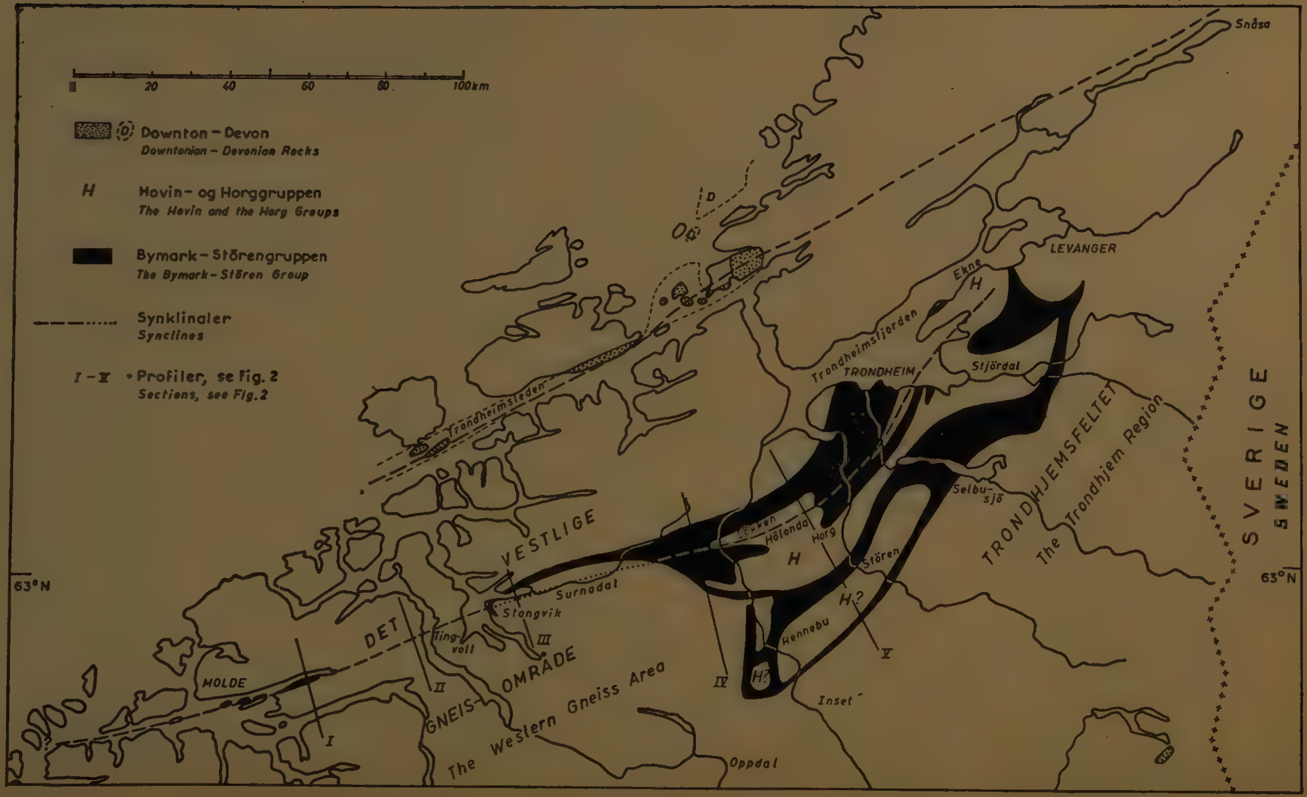

Fig. 1. Kart over Midt-Norge. *Map of Central Norway.*

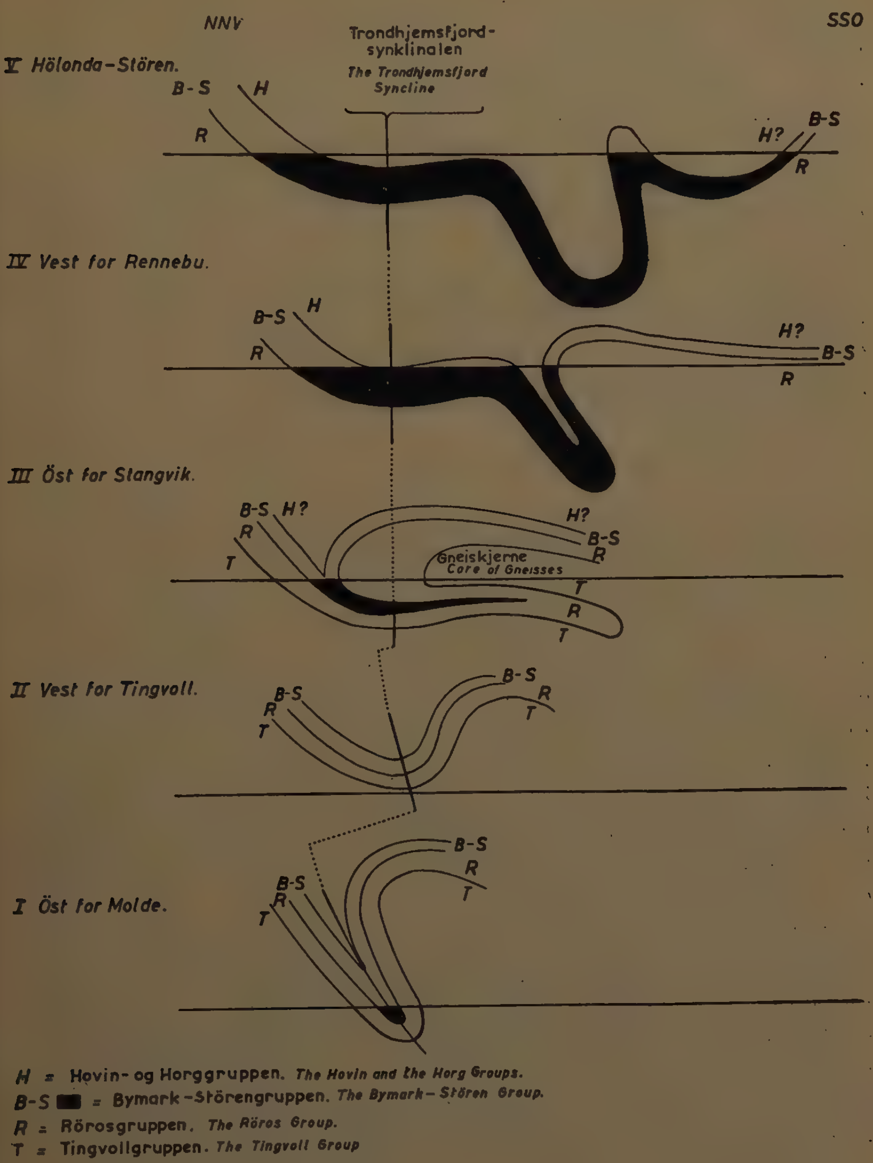
NNV
SSO
Trondhjemsfjord-synklinalen
The Trondhjemsfjord Syncline
V Hölonda-Stören.
B-S
H
R
H?
B-S
R
IV Vest for Rennebu.
B-S
H
R
H?
B-S
R
III Öst for Stangvik.
B-S
H?
R
T
H?
B-S
R
Gneiskjerne
Core of Gneisses
T
R
T
II Vest for Tingvoll.
B-S
R
T
B-S
R
T
I Öst for Molde.
B-S
R
T
B-S
R
T
H = Hovin- og Horggruppen. The Hovin and the Horg Groups.
B-S ■ = Bymark-Störengruppen. The Bymark-Stören Group.
R = Rörosgruppen. The Röros Group.
T = Tingvollgruppen. The Tingvoll Group

Fig. 2. Profiler fra området Molde—Trondheim. *Sections from the Molde—Trondheim district, Central Norway.*

i det skifrene går i luften i det mellomliggende område. Dette forhold henger sikkert sammen med selve synklinalens form, p.g.a. den isoklinale form ved Molde får synklinalen der en meget større vertikal utbredelse enn ved Stangvik. I forhold til hele områdets geologi, med de ovenfor beskrevne antiklinaler, mener jeg derfor at denne kulminasjon er av underordnet betydning. Allerede Tingvollgruppen viser dessuten at kulminasjonen er forholdsvis svak, og at vi sogar har en depresjon vest for Tingvoll.

Videre østover, fra Surnadal til Hølondafeltet, må Trondhjemsfjordsynklinalens foldningsakse stort sett antas ha et østlig fall, i det vi østligst har bevart synklinalens stratigrafisk høyestliggende gruppe, Hovingruppen.

Den undre liggende fold.

Området ved Stangvik er etter min mening et nøkkelområde for forståelsen av Trondhjemsfjordsynklinalens plass i den større tektoniske sammenheng. Som jeg har beskrevet i mitt arbeid om Surnadalssynklinalen (HERNES 1956 b) oppfatter jeg den egentlige (Stangvik) — Surnadalssynklinal (i .e. Trondhjemsfjordsynklinalen) og den sønnenforliggende antiklinalen som den undre del av en større tektonisk enhet, en stor liggende fold med tilnærmet horisontalt akseplan. Folden har åpning mot nord og ombøyning mot syd, se profil III fig. 2. Surnadalssynklinalen — som den er tegnet inn på kartene — blir således den liggende folds åpning; eller om en vil, åpningen mellom nordsiden av den egentlige (Stangvik) — Surnadalssynklinal og den overfoldete, inverterte del.

I Hølonda-Horgfeltet oppfatter jeg, som tidligere nevnt, bare Hølondafeltet som en del av Trondhjemsfjordsynklinalen. Hølondafeltet blir da — analogt profilet øst for Stangvik — den undre del av den liggende foldens nordlige del. Horgsynklinalen blir den liggende foldens ombøyning mot syd. Jeg vil her vise til TH. VOGT's profil i hans interessante oversikt over de vekslende oppfatninger av Hølonda-Horgfeltet gjennom tidene (1945, s. 454, fig. 2, 10).

Et interessant spørsmål er fortsettelsen av Horgsynklinalen (i.e. den liggende foldens ombøyning) mot nord—øst. Antas det at den fortsetter over Stjørdalen, vil Hovingruppen gå i luften nord for Stjørdalen, slik at vi her har synklinalens ombøyning i dagen. Bymark-Størengruppen, som nord for Stjørdalen ligger under Hovingruppen, og som sydvest for Stjørdalen ligger over (TH. VOGT 1945, s. 503), kan følges rundt synklinalens ombøyning, og går også i luften nord for Stjørdalen.

I Levangerområdet sees Rørosgruppen under Bymark-Størengruppen, og muligens er vi her helt nede i eokambriske bergarter. Rørosgruppen kan så følges rundt ombøyningen nord for Stjørdalen og sydover.

En sammenligning av den liggende fold ved Stangvik, Støren og Stjørdal viser at folden vider seg ut fra vest mot øst. Den overfoldete, inverterte del blir derved stadig mindre fremtredende mot øst, og folden mister samtidig sin karakteristiske isoklinale og liggende karakter. Som allerede tidligere beskrevet viser Trondhjemsfjord synklinalen fra Molde og østover en tilsvarende utvikling, og jeg antar at vi her er inne på et viktig tektonisk trekk hos kaledonidene i Midt-Norge.

La oss så gå tilbake til Stangvik-Surnadalsområdet.

Den øvre liggende fold.

Et interessant trekk, som jeg har iakttatt både i fjellområdet øst for Stangvik og ved Honstad-Honstadknyken i Surnadalen, er at den overfoldete, inverterte del av den liggende folden i disse strøk viser en tydelig ombøyning oppover. Denne ombøyning gir i høyereliggende strøk nordlig fall. Sammen med nordsiden av den egentlige (Stangvik)) — Surnadalssynklinal danner den derfor en pseudosynklinal.

Jeg antar at denne ombøyning oppover betyr at den ovenfor beskrevne liggende fold med åpning mot nord, oppover går over i en ny liggende fold med ombøyning mot nord, se profil III fig. 2. Dette gir en liggende fold med en gneiskjerne, omgitt av Rørosgruppen, Bymark-Størengruppen, og ytterst Hovingruppen der denne er utviklet.

En slik øvre liggende fold vil naturligvis endre karakter og vide seg ut fra vest mot øst på tilsvarende måte som den ovenfor beskrevne undre liggende fold.

Følger vi så denne ombøyning østover, kommer vi mot Rennebu til et kritisk område. Vest for Rennebu bøyer trondhjemsskifrene sydover, altså over den antatte øvre liggende foldens gneiskjerne. Fra vest mot øst kommer vi her i overensstemmelse med teorien inn i stratigrafisk stadig høyereliggende lag, fra gneisene i kjernen over Rørosgruppens skifre til Bymark-Størengruppens grønnstener. Det stratigratisk høyestliggende parti må vi vente i området ved Støren.

Er denne tolkning riktig må vi videre vente å finne Hovingruppen også i området syd for Støren, og da i første rekke de bergarter som danner Horgsynklinalens sydside. Flere trekk i C. BUGGE's Rennebuarbeide (1910) indiserer at Hovingruppen er utviklet syd for Støren. Bugges Støren-Hovindgruppe er tegnet inn også syd for hans variolitiske diabasdrag, et drag som ser ut til å svare helt til (Bymark)-Størengruppen. Men spesielt vil jeg fremheve hans beskrivelse av den nordligste del av Gulagruppen (s. 27—28). Her beskrives bl. a. en sandsten med samme utseende som Hovinsandstenen, en likhet som Bugge gjør oppmerksom på.

Syd for denne antatte sydlige Hovingruppe må vi videre vente å finne Bymark-Størengruppen. På et kart over utbredelsen av (Bymark)-Størengrønnstenen i Trondhjemsfeltet har TH. VOGT (1946, fig. 1) tgenet inn en sone med grønnsten fra den midtre del av Selbusjøen og over til nord for Inset. Det ser ut til at vi i området syd for Støren har en forholdsvis flat synklinal, en sydlig parallell til Hølondafeltet. Øverst har vi Hovingruppen, derettet Bymark-Størengruppen, og underst Rørosgruppen, som sees i dagen videre sydover.

Rørosgruppen kan følges nord-østover inntil den går sammen med den ovenfor beskrevne Rørosgruppe i Levangerområdet.

Mot sydvest kommer vi inn i Oppdalsfeltet. Det er i den senere tid undersøkt av en rekke geologer, og senest beskrevet av P. HOLMSEN (1955). Holmsen gir i sitt arbeide en oversikt over tidligere undersøkelser.

Etter Holmsens beskrivelse ser det ut til at Bymark-Størengruppen og Hovingruppen fortsetter inn i Oppdalsfeltet, som en fortsettelse av synklinalen syd for Støren.

I de to liggende folder, den undre med åpning mot nord, og den øvre med ombøyning mot nord, kommer vi fra vest mot Hølonda-Størenområdet inn i stratigrafisk stadig høyereliggende lag. Foldene er skåret skjevt over av den nuværende landoverflate, slik at vi mot vest får stadig dypereliggende snitt.

Dette trekk gjør seg gjeldende innen Oppdalsfeltet. Feltets petrografi og struktur, med buede og mere øst-vestlige soner, ser ut til å passe godt inn i min fremstilling av den kaledonske tektonikk i Midt-Norge.

Vi har altså — etter min mening — et dyptgående V-SV-lig foldesystem, som ble anlagt allerede i tidlig kaledonsk tid, som viser at Trondhjemsfeltet fortsetter direkte inn i Det vestlige gneisområde, og som i dette området antakelig også danner den kaledonske fjellkjedes hovedretning.

Setter vi dette resultat inn i den større kaledonske sammenheng, får vi en fjellkjede som danner en stor bue inn i Midt-Norge med konveks side mot syd-øst, men som mot syd går over i en bue med konkav side mot syd-øst.

En slik buet fjellkjede gir en forklaring på de sammensatte foldesystemer vi har i fjellkjeden. Det er videre naturlig at foldningsfasene har funnet sted til forskjellige tider langs fjellkjeden og med forskjellig styrke.

Vestlandets devon med tydelig V-Ø-lig hovedretning, opptrer i et N—S belte, og en må regne med trykkvirkninger både fra nord og vest, i overensstemmelse med fjellkjedens antatte forløp.

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THE GEOLOGY OF THE ØRSDALEN DISTRICT. ROGALAND, S. NORWAY

BY

KNUT HEIER

Abstract. The tungsten and molybdenite deposit in the area has been dealt with earlier by the author; this paper deals with the general geology, petrology and rock metamorphism of the region.

After the regional geology has been briefly described, the paper deals with the petrographical classification of the rocks exposed. These are amphibolites and two types of quartzo-feldspathic gneisses.

Then follows a short description of the rock structures. It is shown how a heavy folding of orogenic nature has affected all the rocks and it is concluded that they must have reacted to the folding in a plastic way.

A chapter where the metasomatic processes are discussed follows next and the conclusions reached are that the one kind of the gneisses may have originated through metasomatism of anorthositic rocks while strong evidence is that the other has been formed by replacement of amphibolites and related rocks. The metasomatism is believed to be synkinematic.

The metamorphism is dealt with at some length and it is shown that all the rocks must once have belonged to granulite facies, which is also the PT conditions during which the metasomatism took place. Later a retrograde metamorphism has affected the rocks within certain zones which are believed to represent tectonical zones of weakness. A map showing the metamorphic situation of the area is presented and here a division of the rocks into three groups according to differences in metamorphism is undertaken. These are: high amphibolite facies (including granulite facies), low amphibolite facies, epidote amphibolite-and greenschist facies. It is shown how a division of the rocks into one of these three groups can be based upon variations in the minerals of the quartzo-feldspathic gneisses alone.

The paper ends with some considerations upon the relative age of the Telemark and Egersund formations of pre-Cambrian rocks. Based on the data known today the author considers a contemporaneous origin as being most probable.

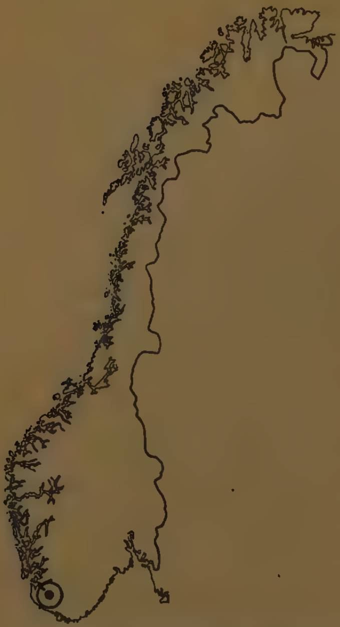


Fig. 1. Map showing the situation of Örsdalen.

Locality.

The area examined is situated in S. Norway and covers the region from Örsdalen (Rogaland) in the north-west to Gyadalen (Vest-Agder) in the south-east, an area of about 45 km^2. (fig. 1).

Topography and climate.

The lake Örsdalsvannet stretches for more than 16 km. in a north-easterly direction, and the width never exceeds 1 km. The altitude of the lake-surface is 64 m but the bottom of the lake is well below sea level. At the south-west end the lake is dammed by a moraine which is supposed to be connected with the glacial deposit known in Norwegian quaternary geology as the Vestfold-raet. As a continuation of the lake towards north-east the valley of Örsdalen rises gently, with a width never exceeding 700 m, for about 10 km to Bjordal where the altitude is 212 m. The valley was iceformed and has a typical U-profile. On both sides the mountains rise, in some places nearly vertically, to altitudes between 600 and 800 m (fig. 2).

The mountain plateau is ice-scoured and most of the soil has been carried away, leaving excellent exposures for detailed geological mapping. Trees are only found in the valleys and on cliffs which intersect the area and give it a rugged appearance.

The topography is strongly dependent upon the rock structures and a study of a topographical map will give the broad outlines of the strike and dip directions of the rocks.

The highest top within the area is Mjåvassknuten with an altitude of 843 m.

The climate is typical for the Norwegian west coast with much rain in the summer. In normal winters there are no continuously frozen periods in the valley itself, but the mountains are snow-covered from December to April, and on the cliffs the snow lasts even longer.

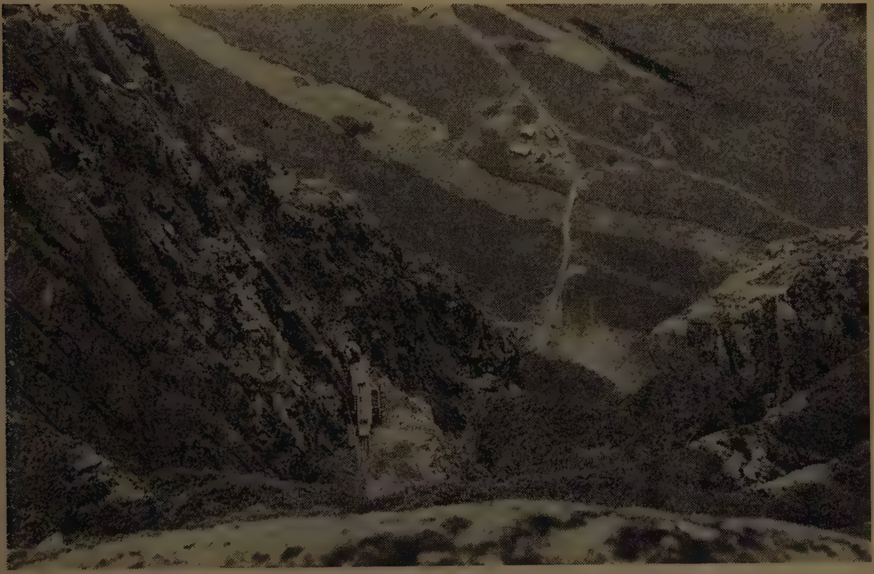


Fig. 2. View of the mountain precipice from the top of the mountain plateau. Schånings mine is seen a little below the top and some houses belonging to the mine are seen down in the valley. The vertical distance from the valley floor to the mountain plateau is at this place about 500 m. (photo, Dr. H. Björlykke).

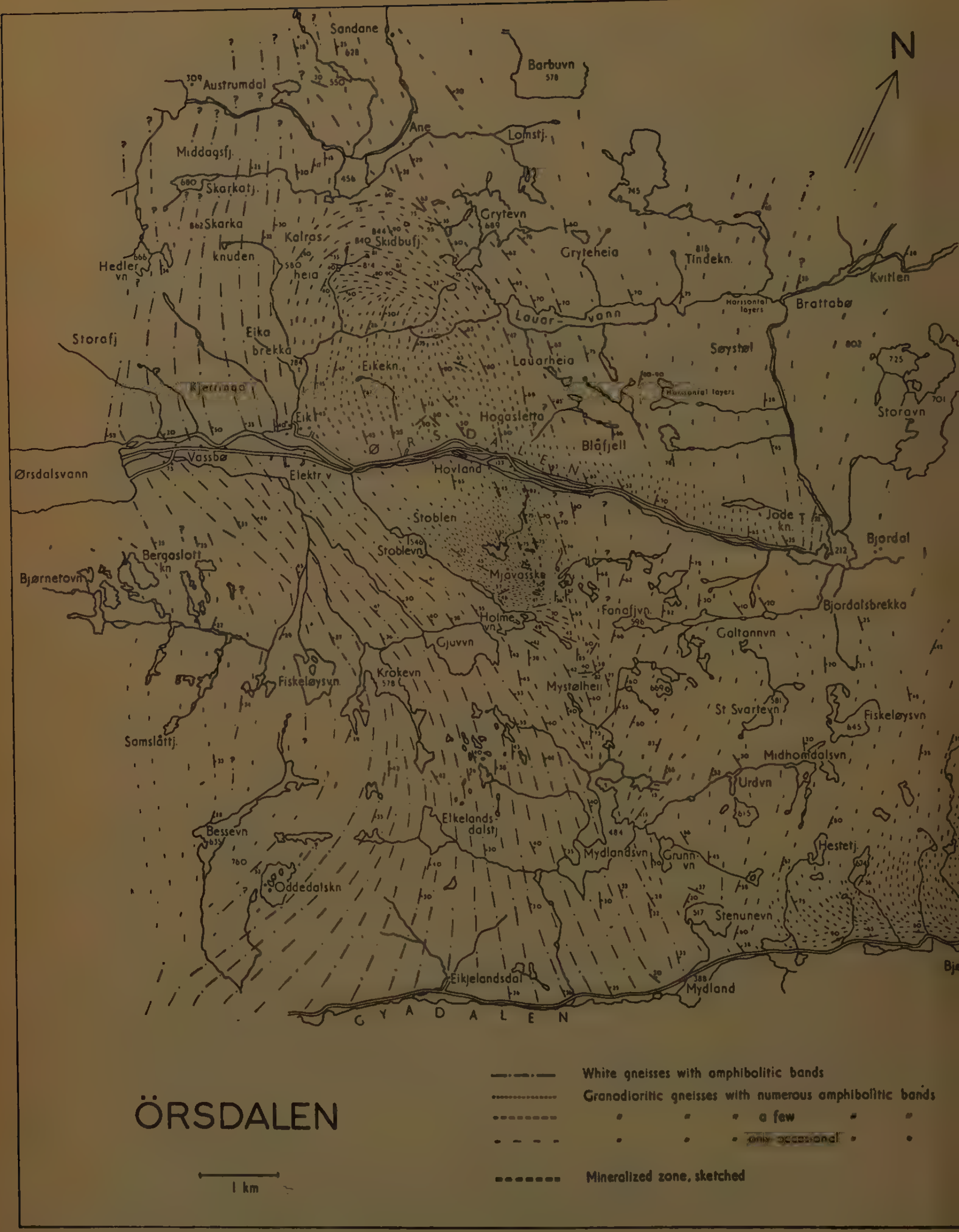
Earlier geological work.

Not much is published about the geology of the area. The tungsten deposits occuring there are briefly mentioned by Brögger (1906, 1922), Foslie (1925), Oftedal, (1948), and Adamson and Neumann (1952). In connection with a description of the Knaben molybdenite mines, Bugge briefly mentioned the deposit in Holtedahl (1953, pp. 114—116). Barth (1945) gives a map of the geology of South Norway (1 : 300 000) which also covers Örsdalen.

In most of these papers the tungsten deposit is just briefly mentioned and nothing is said about the general geology around the deposit.

Own work.

The work was carried out on behalf of A/S Norsk Bergverk, the present owners of the mine, and the field work was done during the summers 1952—53—54. The work was concentrated about the tung-



ÖRSDALEN

N
Sandane
Barbuvn
Austrumdal
Middagsfj.
Ane
Lomstj.
Skarkatj.
Skarka
Kalras
Skidbufj.
Grytevn
Gryteheia
Tindekn.
Kvitlen
Brattabø
Horisontal layers
Hedler vn
knuden
heia
Lauarvann
Søystøl
Storafj
Eika brekka
Eikekn.
Lauarheia
Storavn
Kjerringa
Horisontal layers
Hogasletta
Eik
Ø R S D A L E N
Blåfjell
Ørsdalsvann
Vassbø
Elektr v
Hovland
Jode kn.
Stoblen
Bjordal
Bergaslott kn
Stoblevn
Bjørnetovn
Mjåvasske
Fanafjvn.
Bjordalsbrekka
Holme vn
Galtannvn
Gjuvvn
Krokevn
Fiskeløysvn
Mystølheii
St Svartevn
Fiskeløysvn
Samslåttj.
Midhomdalsvn
Urdvn
Bessevn
Eikelandsdalstj
Hestetj.
Mydlandsvn
Grunnvn
Oddedalskn
Stenunevn
Eikjelandsdal
Mydland
G Y A D A L E N
White gneisses with amphibolitic bands
Granodioritic gneisses with numerous amphibolitic bands
" " " a few " "
" " " only occasional " "
Mineralized zone, sketched
1 km

sten deposit and this represents a central part of the mapped area. A description of the deposit itself has been given earlier (HEIER 1955a) and it will not be treated any further in this paper.

A discussion of some feldspar perthites found within the area has also been previously published (HEIER 1955b). The aim of this paper is to give a description of the general geology of the area.

REGIONAL GEOLOGY

The area represents a border zone between the Egersund formation of anorthositic and monzonitic rocks and the more alkalic gneiss-granites of the Setesdal-Telemark region, both of believed pre-Cambrian age. The oldest name for these rocks was «The grey gneiss of Dalane». BARTH (1945) used the name Birkremite which is the name of a hypersthene bearing granitic rock belonging to the charnockite family, or rather granodioritic rocks of granulite facies affinities, occuring in connection with the Egersund formation. On the new geological map of Norway by Holtedahl and Dons the neutral name «gneisses in general» is used.

The nearest anorthositic body is found about 10 km to the southwest of the mapped area and towards the northeast we enter the geologically little-known area of gneisses with granitic affinities covering the huge area of Rogaland, Aust-Agder and Setesdal. These rocks are thought to be associated with the pre-Cambrian Telemark granite, the central part of which is about 120 km NE of Örsdalen.

In the Örsdalen area we find a heterogeneous complex of mixed rocks or what would generally be named migmatites: composed of basic rocks with gabbroic or rather amphibolitic affinities and quartzo-feldspathic gneisses. The latter can be divided into two groups one of which is of a common granodioritic composition.

All these rocks have reacted to the same pressures which have induced a parallel foliation upon them.

Quartz veins occur all through the area and seem always to be parallel with the general foliation.

Minor pegmatites occur inside weakly foliated granodiorites with an elongation usually vertical to the general rock foliation.

Of uncertain age, but obviously younger than the other rocks, is a diabase dyke which is found in the Örsdalen valley, striking

N7OE and cutting through the general rock foliation (not marked on the map). Similar dykes of a young age are frequent within the Egersund formation.

As shown on the attached map the rock foliation varies within large limits. The structures will be discussed in some detail in a later section of this paper, and at this stage attention will just be drawn to the fact that the variations are gradual and the rocks are never seen to be crushed or mylonitized where the strike is turning. The rocks must have reacted to the pressure in a plastic manner.

PETROGRAPHY

Amphibolites.

The amphibolites occur as bands and lenses of minor size within the gneisses all over the mapped area. They seem to be most frequent within the central part, where the ore is also found, and can here be followed continuously in the direction of the strike for several 100 meters with a width usually between 10 and 20 meters. Generally they are, however, small and show all transitions towards complete assimilation in the quartzo-feldsapthic gneisses.

In the amphibolites the following minerals are found: Quartz (secondary), plagioclase, rhombic and monoclinic pyroxene, hornblende, biotite, chlorite, serpentine, epidote, zoisite, garnet, apatite, sphene, zircon and iron ore (usually magnetite, but also hematite and ilmenite may occur).

Table 1 gives the mineral distribution as determined by «point counter» on thin-sections of 7 amphibolites from different localities within the area.

As seen from the table the amount of plagioclase, or rather plagioclase plus zoisite[1]) (all the plagioclases except no. 1 have undergone a varying degree of saussuritization), is kept nearly constant all through the series. In no. 5 where the plagioclase is of the composition of nearly pure albite, a heavy saussuritization has taken place, indicating a much more basic primary composition. The plagioclase

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[1]) In the rocks examined I have not been able to demonstrate whether zoisite or clinozoisite is formed by the saussuritization processes. In this paper the term zoisite will be used for the mineral thus formed.

Table 1.

The mineral distribution in seven amphibolites.

	1	2	3	4	5	6	7
Quartz	—	—	+	—	—	—	—
Plagioclase[1] ...	46 An_{60}	32 An_{48}	46 An_{38}	40 An_{30}	40 An_{4}	45 An_{40}	45 An_{36}
Hypersthene ..	17						
		15	—	—	—	45	—
Diopside	+		16	10	—	—	—
Hornblende ...	32	40	18	35	—	—	55
Biotite	5	10	6	—	—	+	+
Chlorite.......	—	—	11	5	(32	—	—
Serpentine	—	—	—	—	25)	—	—
Iron ore	+	2	1.5	10	2.5	10	+
Apatite	—	11	1.5	+	0.5	+	—

+ indicates very small amounts of the mineral.

1. Gyadalen (between Mydland and Eikjelandsdal).

2. Holmevann — Mjåvassknuten.

3. Hovland — Eikeknuten.

4. Hellarsfjell west of Stoklevann. 5. Okterdagsheia close to Krokevann.

6. Bergaslottknatten. 7. Eikebrekka (658 m.)

is usually of about the same size as the other minerals but can in some cases attain the character of porphyroblasts.

The femic minerals vary as seen in the table, according to the metamorphic grade. No. 1 with the rather basic plagioclase and where the pyroxene is dominantly rhombic must be recognized as belonging to granulite — or the higher part of amphibolite facies. In no. 2 the amount of diopsidic pyroxene has increased and the rock has more the character of belonging to amphibolite facies. In no. 3 chlorite occurs in appreciable amounts while the other minerals suggest an amphibolite facies for this rock. No. 4 corresponds to the border between amphibolite- and epidote amphibolite facies if the equilibrium plagioclase An_{30} — zoisite should characterize this transition No. 5 represents a very low metamorphic rock in greenschist facies.

The rocks 1—5 illustrate a series of continuously decreasing metamorphism.

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[1] The amount of «zoisite» occurring as a product of the saussuritisation processes, is included together with the plagioclase in the table.

In no. 6 the only femic minerals are pyroxene and iron ore while in the high metamorphic no. 1 appreciable amounts of hornblende and biotite were present. In no. 7 hornblende is the only femic mineral while diopsidic pyroxene could be expected to occur in this rock.

The rhombic pyroxene of no. 1 is weakly pleochroic, biaxial neg, 2V about 60°. The refractive indices are:
$n\gamma = 1.719 \pm 0.003$, $n\beta = 1.709 \pm 0.003$, $n\alpha = 1.705 \pm 0.002$. This corresponds to a composition of 35—40 mol % $Fe_2Si_2O_6$[1].

The refractive indices of the rhombic pyroxene of no. 7 were determined as: $n\gamma = 1.715 \pm 0.004$, $n\beta = 1.705 \pm 0.004$, $n\alpha = 1.699 \pm 0.002$ indicating a composition of about 30 mol % $Fe_2Si_2O_6$.

The refractive indices of the diopsidic pyroxene of sample No. 4 and 6 were determined:

No. 4 . $n\gamma = 1.725$, $n\beta$ 1.704 ± 0.004, $n\alpha$ 1.695 ± 0.002
No. 6 . $n\gamma = 1.728 \pm 0.002$, $n\beta = 1.709 \pm 0.002$, $n\alpha = 1.695 \pm 0.002$

This indicates a composition of about 50 mol % of the hedenbergite component.

In samples no. 1, 3, and 4 the pleochroism of the hornblende varies between light brown and dark greenish brown, while in no. 2 and 7 the pleochroism is : x, light green, y, dark green, z, brown The refractive indices vary as follows:

No. 1 . $n\gamma = 1.670 \pm 0.003$, $n\beta = 1.665$, $n\alpha = 1.654 + 0.002$
No. 4 . $n\gamma = 1.670 \pm 0.002$, $n\beta = 1.668 \pm 0.002$, $n\alpha = 1.654 \pm 0.001$
No. 7 . $n\gamma = 1.670 \pm 0.002$, $n\beta = 1.662 \pm 0.002$, $n\alpha = 1.652 \pm 0.002$

Despite the somewhat differing pleochroism, the refractive indices are closely similar and indicate a hornblende with a composition of about 35 mol % of the (Fe,Mn,Ti) component or according to Tröger they are belonging to the most common hornblendes.

Diopside-biotite schists.

Rocks which petrographically may be classified as mica-schist occur very subordinately in the field. Their occurrence is similar to that of the amphibolites as lenses in the surrounding granodiorite and with a foliation always parallel to the gneisses.

Table 2 gives the mineral distribution in one of the mica-schists.

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[1] For the optical determinations the tables of Tröger (1952) were used.

Table 2.
Pyroxene-biotite schist. 250 m. SW of Fanafjellsvann.

Quartz	5 %
Pyroxene	26.5 %
Biotite	66.5 %
Apatite	1.0 %
Ore	1.0 %

(Accessory zircon occurs in the biotite).

The schist is coarse-grained with biotite flakes of several mm and also the pyroxene can be larger than 1 mm. All the pyroxene is diopsidic.

The quartz grains are small and have an undulatory extinction.

«The white gneisses of Örsdalen».

As mentioned before the quartzo-feldspathic rocks can be divided in two groups, the one of which I have named «The white gneisses of Örsdalen». The occurrence of these rocks within the area is shown on the attached map. They are not restricted in their occurrence to Örsdalen. Similar rocks are found along the strike at Hofsherad some miles further SE. (NEUMANN, HEIER and HARTLEY 1955). Rust zones are frequent within these rocks and at Hofsherad graphite is found along the foliation planes.

These gneisses are characterized by their pure white colour and can be seen to consist mostly of quartz and feldspar. They are remarkably poor in femic minerals, the amount of which only seldom exceeds 5 %. Red garnets occur typically contrary to what is the case in the ordinary granodioritic gneisses to be described later. (Garnets are typical of this gneiss series as a whole, but they are scattered throughout the rocks and handspecimens might well be picked containing no garnets at all. This is clearly demonstrated in table 3 where just 2 out of 9 samples contain garnets). The grain size varies within large limits and when coarse-grained they may take on a pegmatitic appearance. They occur together with amphibolitic lenses and often as pegmatitic veins within these. The contacts with the amphibolites are often sharp but may also be gradual resulting in an increase of femic minerals in the white gneisses and giving them an appearance not much different from the ordinary granodiorites.

Table 3.

	1	2	3	4	5	6	7	8	9
	%	%	%	%	%	%	%	%	%
Quartz	34.26	45.0	43.0	32.0	27.0	7.0	11.0	34.0	36.0
Microcline	+	17.0	26.0	28.0	45.0	71.0	78.0		5
Orthoclase		—	—	—	—	—	—	64.0[1]	— 49[1]
Plagioclase[2]	$48.03An_{48}$	$37.0An_{28}$	$30.0An_{28}$	$32.0An_{6}$	24.0Ab	$12.0An_{34}$	7.0		10
Epidote	—	—	—	8.0	—	—	—	—	—
Sericite	2.24	+	1.0	—	+	2.0	+	+	+
Garnet	11.20	—	—	—	—	—	—	2	—
Hypersthene	—	—	—	—	—	4.0	—	—	—
Biotite	2.88	—	—	—	—	2.0	4.0	—	+
Chlorite	—	1.0	+	+	4.0	—	—	—	+
Iron ore	1.39	—	+	+	+	2.0	+	—	—
Rutile	+ ?	—	—	—	—	—	—	—	—
Zircon	+	—	—	—	—	—	—	—	—
Apatite	—	—	—	—	+	+	—	—	—
	100	100	100	100	100	100	100	100	100

(+ indicates that the mineral occurs in very small amounts.)

(In the samples 8 and 9 most of the feldspar occurs as «mesoperthites».

1: Gyadalen, 400 m NE of river between Eikjelandsdal and Mydland. 2: Close to big bend of river W of Mydlandsvann. 3: 1 km SW of Grunnvn (Mydlandsvann). 4: Gyadalen, 300 m NE of Eikjelandsdal. 5: Close to the river between Eikjelandsdal and Mydland in Gyadalen. 6: Roadcut, Örsdalsvannet. 7: Krokevann. 8: At the south end of Mydlandsvann. 9: Middagsfjell.

[1] 64 and 49 represent the percentage of mesoperthite in these rocks.

[2] Plagioclase and zoisite are counted together. The epidote of no. 4 is not a product of saussuritization processes, but is found in secondary quartz-epidote veins (see text).

These gneisses are usually strongly foliated with a foliation parallel to that of the other rocks. In roadcuts i Örsdalen and Gyadalen, where excellent exposures of the rocks are available, the foliation is not so marked and it is especially across the mountain between the two valleys that it shows up. Here we find an intense pressing which together with the alternating white gneissic- and dark amphibolitic bands gives «the impression» of an originally sedimentary layering.

In field appearance the white gneisses are so similar that it is not possible to divide them into subgroups. Thin section studies show a remarkable variation, however, as well in chemistry as mineralogy. Table 3 gives the mineral distribution as determined by point-counter of some of these rocks.

The femic minerals vary between hypersthene, garnet, biotite, chlorite and iron ore according to the metamorphic grade, which as a rule is low for these rocks, but even in the lowest metamorphic types relicts of such high metamorphic minerals as hypersthene can be seen.

It is the variations in the feldspars which are of particular interest. The numbers 1—7 in table 3 show a continuous increase in the potash feldspar content at the same time as the amount of plagioclase decreases. In no. 1 potash feldspar just occurs as antiperthites while in no. 7 most of the albite occurs as lamellae in perthites. The intermediate and latter types are most frequently met with and there is a rapid transition from rocks of type 1 to more potash rich types. In the latter types antiperthites also occur. In no. 8 and 9 most of the feldspar is of the type named «mesoperthites» by MICHOT (1951): a feldspar with such an intimate intergrowth that it is impossible to discriminate between the exsolution phase and the host. (photo 1, plate 1)). A theory that replacement processes are responsible for the formation of these perthites has been published earlier by the author (1955 b).

Examples of potash feldspar replacing plagioclase in a more ordinary way are frequently seen in thin sections (photo 2, plate 1), and along the border between potash feldpar and plagioclase myrmekitic quartz occurs within the plagioclase (photo 3, plate 2).

The composition of the plagioclases is seen from table 3 to vary from basic andesine to pure albite. In the latter cases the plagioclases are heavily saussuritized, however, indicating a primary more basic composition. (The amount of plagioclase and zoisite are counted

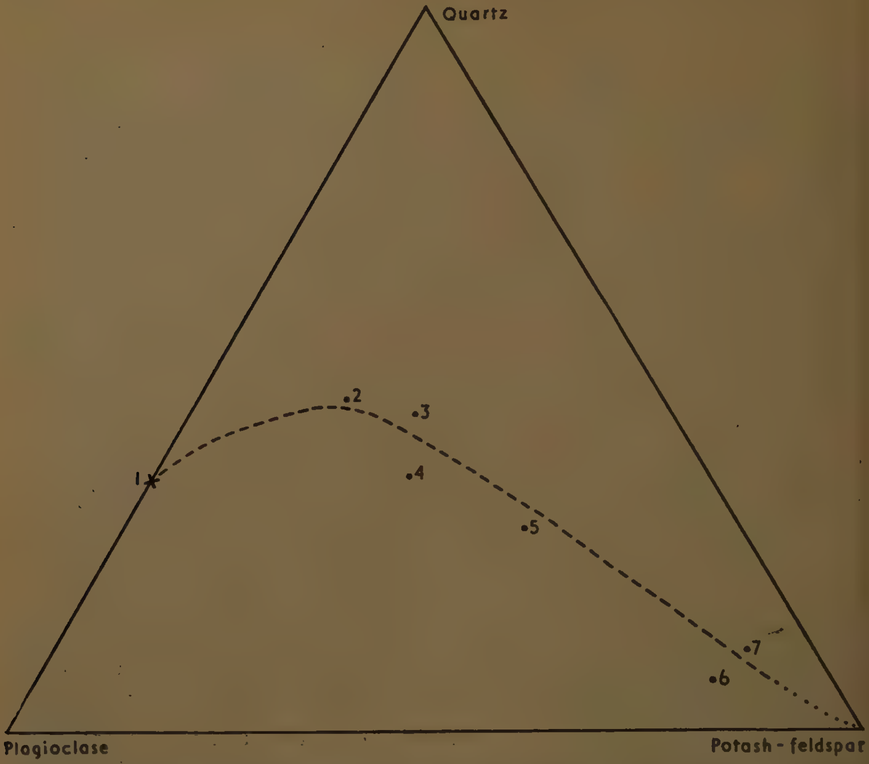

Fig. 3. Plots of the white gneisses (nos. 1—7 table 3) in a quartz — plagioclase — potash feldspar diagram.

together in the thin section analyses and listed as plagioclase in the table). The epidote listed in no. 4 is a constituent of secondary quartz veins which in thin sections are seen to penetrate all the other minerals in this rock.

The quartz grains are often of a blue colour and may contain inclusions of rutile showing sagenite structures (photo 4 pl. 2). In the strongly foliated rocks the quartz occurs as narrow veins parallel to the foliation and may attain a length of several cm.

In fig. 3 the rocks 1—7 of table 3 are plotted on a quartz, plagioclase and potash feldspar diagram. The rocks where «mesoperthites» are the only feldspar phase will be situated close to no. 3 and 4 in this diagram (for analyses see HEIER 1955 b).

Quartz-monzonitic and granodioritic gneisses.

These rocks cover most of the surface within the mapped area. They are usually somewhat richer in femic minerals than are the white gneisses and their colour is grey or reddish. The texture varies from fine-grained aplitic to pegmatitic, the bulk being a medium-grained rock. There are no sharp contacts between the different types, and minor pegmatitic parts can be seen well inside the fine-grained ones. In places the granodiorites transform into augengneisses where the porphyroblasts consist of rather pure perthites.

The following minerals are found in these rocks:

Quartz
Potash feldspar
Plagioclase
Zoisite
Epidote
Sericite
Garnet
Hypersthene
Diopside
Hornblende
Biotite
Chlorite
Iron-ore
Sphene
Zircon
Apatite

In table 4 the result of 13 pointcounter analyses of these rocks is listed.

As seen from the table the quartz content varies between 20—40%. Usually it is, however, around 30 %. It always shows an undulatory extinction. Three generations of quartz occur: 1. primary quartz, 2. myrmekite quartz spindles inside the plagioclase along the potash feldspar contacts are met with in nearly all the thin sections (photo 5, plate 3), 3. secondary quartz veins with chlorite and epidote penetrating the other minerals in the low metamorphic rock types.

Potash feldspar occurs both as orthoclase and microcline perhite. Mesoperthites do occur but are, contrary to what was found for the white gneisses, rare in these rocks. The amount of potash feldspar may vary between 20—50 %, but is in most cases around 30 %. It is usually fresh but can be somewhat sericitized in the low metamorphic types.

Table 4.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	%	%	%	%	%	%	%	%	%	%	%	%	%
Quartz	34.8	42.2	31.0	27.2	31.4	21.0	29.6	26.8	30.1	26.5	23.3	34.6	31.0
Orthoclase	28.6	31.2	—	34.0	26.7	47.0	—	—	—	—	21.7	—	—
Microcline	—	—	40.2	—	—	—	39.4	42.1	39.4	45.0	—	49.3	44.3
Plagioclase[1]	22.1 An_{38}	21.5 An_{38}	22.0	30 An_{38}	34.8 An_{33}	28.2 An_{34}	26.6Ab	28.2	27.5 Ab	26.6 Ab	39.1 An_{40}	14.0 An_{36}	22.0 An_{38}
Zoisite	2.0	—	—	—	—	—	—	—	—	—	—	—	—
Epidote	—	—	—	—	—	—	1.0	+	0.3	+	—	—	+
Sericite	—	—	—	—	—	—	—	+	—	+	—	+	0.6
Garnet	—	—	—	—	—	—	—	—	—	—	—	2.1	—
Hypersthene	—	—	—	0.7	2.7	—	—	—	—	—	4.2	—	—
Diopside	—	—	—	—	0.7	—	—	—	—	—	—	—	—
Hornblende	5.5	—	—	2.1	—	—	—	—	—	—	—	—	—
Biotite	3.5	2.0	2.4	3.2	0.4	0.8	—	2.3	—	+	—	+	—
Chlorite	0.5	1.1	1.8	a	2.0	2.5	3.0		2.7	2.0	—	—	1.7
Iron Ore	2.5	2.0	2.6	2.5	2.3	0.5	0.4	0.6	0.3	+	2.7	—	0.4
Sphene	—	—	—	+	+	+	—	+	—	—	—	—	—
Zircon	+	+	—	—	—	+	—	—	—	—	—	—	—
Apatite	0.5	—	—	0.3	+	+	+	—	—	—	—	—	—

(+ indicates that the mineral occurs in very small amounts.)
(a: Hypersthene is here altered into a chloritic aggregate.)
1. Coarse-grained gneiss. Diamond drill core between Schåningsgrube and Wolframsynken close to the mineralized zone.
2. Fine-grained gneiss
3. Fine grained gneiss. Tunnel along the mineralized zone in Örsdalen. 4. Coarse-grained gneiss Mjåvassknuten. 5. Coarse-grained gneiss Skidbufjell. 6. Medium-grained gneiss Blåfjell. 7. Medium-grained gneiss Åne. 8. Coarse-grained gneiss, Fanafjellsvann — Galtanvanns-draget. 9. Coarse-grained gneiss Mydland in Gyadalen. 10. Coarse-grained gneiss Björnstadvann. Gyadalen. 11. Medium-grained gneiss ca. 500 m NW of Fiskelöysvann. 12 Medium-fine-grained gneiss. Bergaslottknatten. 13. Coarse-grained gneiss Bessevatn.

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[1] When the amount of anorthosite in the plagioclase is not listed in the table it is because the heavy saussuritization has made the optical determination of this quantity impossible (ex. 3.8), the same is the case when the composition is just listed

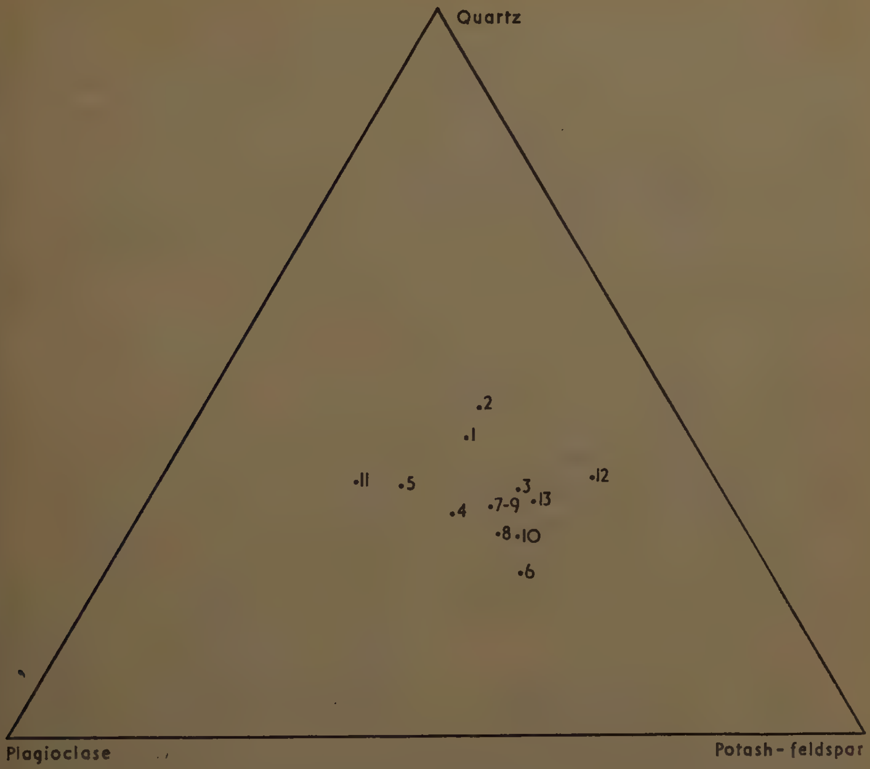

Fig. 4. Plots of the granodiorites of table 4 in a quartz — plagioclase — potash feldspar — diagram.

When not secondarily altered the plagioclase is generally of the composition An_{38}—An_{36}. In table 4 all the plagioclases with a composition more acid than andesine are saussuritized, but unaltered oligoclases can be found within the area. When the composition becomes albitic they are, however, always saussuritized. (The saussuritized plagioclases are counted as plagioclase in the table). Antiperthites are frequent also within these gneisses (examples 1, 4, 5, 6, 7, and 13 in table 4.)

The femic minerals vary according to the metamorphic grade and it should be noted that also here chlorite is found within rocks where the other minerals indicate an amphibolite facies. Hypersthene occurs and the rocks are thus related to the birkremites connected with the

Egersund formation. Usually the hypersthene is altered, however, and in may cases chlorite seems to be the alteration product. In the very low metamorphic types the hornblende and biotite also become chloritized, but in many cases fresh hornblende is seen along the contact of heavily altered hypersthene (photo 6, pl. 3).

In fig. 4 the granodiorites are plotted on a quartz, plagioclase and potash feldspar diagram similar to the one used for the white gneisses. It is seen that the former are much closer spaced on this diagram indicating a more uniform composition.

Pegmatites.

The granodiorites can in some cases be so coarsegrained that they attain the appearance of pegmatites, but apart from this real pegmatites are rare in Örsdalen and they are not of any important size.

A small pegmatite within the mineralized area is sketched in fig. 5. It occurs within a nearly homogeneous gneiss and strikes N45°W, dipping 73° to NE. The pegmatite is not more than 15—20 cm broad, in one end it wides out to around 40 cm but is here divided in two, surrounding a gneissic rock of the ordinary type. The length is around 2.5 m in a direction N75°E and thus cutting the foliation of the gneiss. An amphibolitic band occurs just 10 cm away from the one end of the pegmatite.

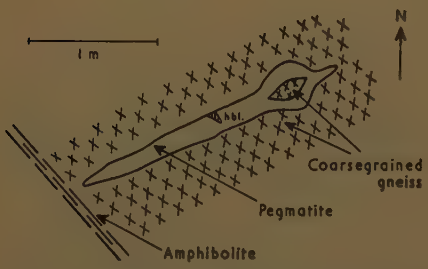

Fig. 5. Sketch drawing of a small pegmatite body in Örsdalen.

The following minerals are found within the pegmatite: quartz, potash feldspar, hornblende, biotite and magnetite.

The quartz and potash feldspar are the main constituents of the pegmatite and the two minerals are always intergrown giving the pegmatite a graphic appearance. The potash feldspar is found in crystals of some cm and is an orthoclase perthite.

The hornblende crystals may attain the dimensions of several cm and they show a pronounced tendency to orientate themselves with the C axis vertical to the contact between gneiss and pegmatite, or, what is the same, parallel to the foliation of the gneiss. The pleochroism is: x light green, y green, z dark green — brownish green, and the refractive indices: $n\gamma = 1.692 \pm 0.001$, $n\beta = 1.687 \pm 0.002$, $n\alpha = 1.669 \pm 0.002$, $n\gamma - n\alpha = 0.023$. According to the tables of Tröger this indicates a hornblende with around 60 mol % of the (Fe, Mn, Ti,) component or much more iron-rich than the hornblende of the amphibolites.

Quartz veins and lenses.

Massive quartz veins occur all through the area but probably in greatest quantity within the mineralized part. Usually they are found within the coarse-grained granodiorite, but also in the amphibolites and along the contact between the two. Close to the veins the amphibolite is often altered into a biotite-rich rock.

The quartz veins can be divided in two on the basis of their appearance. The one is greyish and occurs within the mineralized zone in Örsdalen, while the other is of the white milky type occurring all over the area (HEIER 1955 a).

The lengths of the individual veins do not usually exceed some meters, but different veins occur *en echelon* and can be followed several 100 metres. The width is seldom more than 1 m and usually much smaller.

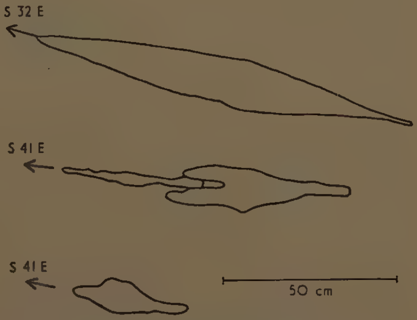

Fig. 6. Typical types of minor quartz lenses occurring in Örsdalen.

Fig. 6 shows typical types of quartz lenses occurring in Örsdalen.

Diabase dyke.

Diabase dykes are frequent within the Egersund region, and it is noted there that they cut through all the other rocks, and must therefore be of a younger age. The true age of the dykes is, however, not known, and besides pre-Cambrian, Cambro-Silurian (Caledonide), Permian and Tertiary are possible epochs for their eruption.

In Örsdalen a diabase dyke is found down in the valley where it is seen to have a direction cutting through all the other rocks. (The dyke is not marked on the attached map).

It is a grey, hard rock which in thin sections shows heavy secondary alteration. It is seen to contain the following minerals: olivine, hypersthene, hornblende, chlorite, serpentine, plagioclase, zoisite and iron-ore.

The olivine occurs as small grains within the serpentine — chlorite aggregate. The hypersthene seems to be rather fresh even in places where it contacts the chlorite. In some places, however, it is altered into hornblende. The plagioclase is always heavily saussuritized. Because of the metamorphic alteration of the diabase a too young age can not be postulated.

STRUCTURES

From the map it is seen how the foliation directions of the rocks vary within wide limits. In the centre an area may be separated showing a kind of an elongated basin fold. On the north-west end of this area the foliation planes dip south-east and at the south-east end they dip north-west. On both flanks the dips are to the north-east, being somewhat flatter on the south-west. The rock foliation strikes conformably around the fold on both sides. It is within this fold on the south-east side of Örsdalen that the tungsten deposit is situated.

In Gyadalen the strike again turns away from the normal, the direction becoming approximately east-west. This is of particular interest as the only molybdenite mineralization occurring outside the main mineralized area in Örsdalen is found within this part, some distance to the north-east of the map. Molybdenite occurs here together with quartz veins of the same type as in Örsdalen and the veins are striking approximately east-west parallel to the rock foliation. It seems therefore that a knowledge of the structural variations will be of prime importance for further prospecting within this area.

A profile made across the centre of the map, from south-west to north-east will show the following features: In the south-west the gneisses are clearly, but not strongly, foliated and the dips average 35° in a north-easterly direction. At Krokevann we enter the strongly foliated white gneisses which together with the alternating amphibolitic bands give an impression of sedimentary layering, but the dip remains the same. When we now enter the central basin folded area the dip becomes progressively steeper and the foliation of the gneisses less pronounced. The average dip is around 75° to the north-east, but within the central part it can be vertical and the granodiorites are sometimes so homogeneous that it is the amphibolite inclusions which define the foliation directions. Further north-east the steeply inclined, weak foliation continues and the amount of amphibolitic inclusions within the gneisses decreases. After a while the foliation flattens out and in places horizontal layering is observed. In the far north-east end of the map the foliation is of the same kind as in the south-west.

From Gyadalen over Krokevann and across Örsdalen in the north-west, where the white gneisses are strongly foliated, we have a natural means of access across the mountains. A similar topographical feature is found along the river from Brattabö to Bjordal, north-east of the basisn folded area. The directions of these two minor valleys in the topography are N45°W or parallel to the axes of the basin fold, and they are believed to represent tectonical zones of weakness in some way connected with the folding.

All the rocks, except the diabase dyke in Örsdalen, have reacted to the same forces and the foliation directions are always parallel. Further, where the strike turns, this always happens gradually and no crushing or mylonitisation is observed, which indicates the rocks to have been in a plastic state during the folding.

Within the Egersund region MICHOT (1951) believes the main migmatisation to be synkinematic and the same seems to be the case in Örsdalen. The metasomatic processes will be treated in some detail in the next chapter and it will then be shown that the main event during these processes is the formation of potash feldspar substituting for the other minerals.

It is seen in thin sections that where the strike turns the plagioclase twin lamellae are often bent but never broken, and the potash feldspar is usually not deformed at all. The homogeneous appearance of the granodiorite within the basin fold also suggest the recrystallisation processes to be contemporaneous with the folding.

The only place where the rock minerals, including the potash feldspars, are seen to be fractured is within the strongly foliated white gneisses, and here also secondary quartz veins are cutting through all the other minerals. It is therefore possible that late movements have taken place when the rocks were no longer in a state of plasticity. These forces cannot, however, have been of any regional nature as they have left the rocks within the basin fold unaffected. The importance of this will be further discussed in the chapter on the metamorphism.

The latest tectonical event in Örsdalen is the opening of fractures with a direction about N70°E. They cannot be seen to have affected the rocks in any way but are marked features in the topography, and are for instance represented by the valleys of Örsdalen and Gyadalen. The reason for their marked relief must, however, be seen in relation to the icemovement which during the last glacial epoch was parallel to these fractures.

METASOMATISM

The rocks within the Örsdalen area represent typical pre-Cambrian migmatites for the formation of which metasomatic processes are highly responsible. It will be shown that the result of these processes is mainly the formation of potash feldspar which is seen to replace plagioclase to a considerable extent in the white gneisses. As regards the granodiorites, which are believed to a large extent to have originated through assimilation of amphibolites and related rocks, the newly formed potash feldspar replaces the femic minerals leaving the amount and composition of the plagioclase intact.

No real doubt can be maintained about the metasomatic origin of the white gneisses. Though closely resembling each other in the field, they show, as indicated in table 3, a remarkable variation in chemistry and mineralogy. Though the intermediate and potash-rich types are most frequently met with today there can hardly be any doubt that the plagioclase-rich types best represent the original rock. In nearly every thin section fine examples of potash feldspar replacing plagioclase can be seen. Antiperthites are frequent within these rocks and the potash lamellae often show the typical microcline cross hatching. In many cases, however, the lamellae have a form in the plagioclase indicating a formation by replacement and not by exsolution. A typical example of this is seen on the photo 7, pl. 4, where the microcline in the centre shows typical replacement contacts against the surrounding plagioclase. Further the microcline in the lower righthand corner of the photo is seen to cut across the boundary of two plagioclase individuals.

The «mesoperthites», which are typical for these rocks, must have originated by the replacement of plagioclase by potash feldspar. (HEIER 1955 b).

Myrmekite quartz is frequently seen within the plagioclase close to the potash feldspar contact in both the white gneisses and the granodiorites. In accordance with DRESCHER-KADEN (1940) the myrmekite quartz must in some way be recognized as related to the replacement of plagioclase by potash feldspar.

Whether the quartz is a primary or a secondary constituent of these rocks is a more complicated problem. From fig. 3 it can be seen that the quartz content first becomes higher and then decreases as the amount of potash feldspar increases. This does not, however, necessarily mean that quartz is a primary constituent being replaced by potash feldspar. The amount of albite which enters the potash feldspar lattice in solid solution will, at least at intermediate temperatures, be much higher than the corresponding amount of anorthite. When therefore potasium is brought into a system containing a basic plagioclase with which it reacts and form potash feldspar, silica also has to be brought into the system according to the equation:

1. $2K^+ \pm CaA1_2Si_2O_8 + 4SiO_2 \rightleftarrows 2KAlSi_3O_8 + Ca^{2+}$

If we consider the total SiO_2 content in the rocks of table 3 the difference is not so marked as indicated in fig. 3. The total SiO_2 content of nos. 6 and 7 will then be approximately the same as in no. 1. (63 cation% SiO_2 in no. 1 as compared with 59 cation % in no. 6 as calculated from the table).

The appearance of the quartz, often as long veins of some cm, not to be mistaken for the much later quartz veins penetrating all the other minerals in the rocks, strongly suggests a secondary origin for this mineral.

If the quartz really is a secondary constituent in these rocks introduced during the general metasomatism of the area, the plagioclase-rich types illustrated by no. 1 in table 3 will have an original composition closely resembling the anorthosites within the Egersund area. The plagioclase of this rock is as well by composition as by its antiperthitic nature identical to the plagioclase of these anorthosites. (photo 8, pl. 4.)

The granodiorites do not differ to any large extent from those usually found within pre-Cambrian migmatite areas, but are maybe somewhat more calcic than these in general.

Over comparatively large areas these rocks can have a homogeneous appearance where any foliation is scarcely to be seen and where inclusions of other rocks are rare. In these places they may in the field be interpreted as magmatic rocks. They are, however, chemically and mineralogically identical with similar rocks elsewhere where a metasomatic origin is beyond doubt. The fine-grained aplitic types, which occur at intervals all over the area, not only within the mineralized part, and which often have a very homogeneous appearance, might be explained as younger intrusions within an old gneissic complex. The contacts between these and the other types are, however, always gradual and even in their centre they may gradually become coarse-grained and even pegmatitic. With respect to mineralogy and chemistry they do not differ from their more coarse-grained neighbours. The granodiorites can in places attain the character of augengneisses which only differ from the more fine-grained types in the size of the potash feldspar individuals. This kind of rock is recognized by most petrologists as being formed during ultrametamorphism.

It seems to the author to be no over-simplification of the problem to assume all the rocks classified as granodiorites within this area to have a common origin. As to the nature of this origin most field evidence beyond doubt points towards a metasomatic one. This agrees with the opinions held by most geologists experienced from similar regions elsewhere.

The only true processes of magmatism believed to have taken place within these regions are those of reomorphism or anatexis. Quartzo-feldspathic rocks formed in this way should be believed to fall within the low temperature trough in the residua system of Bowen (BARTH 1952). This is not the case with the granodiorites in Örsdalen. Fig. 7 is a reproduction of this diagram and the numbers 1, 2, 4, 5, 6, 11, 12, 13 refer to table 4 and represent granodiorites which have not been secondary altered. The letters b — g refer to table 5 to be treated next.

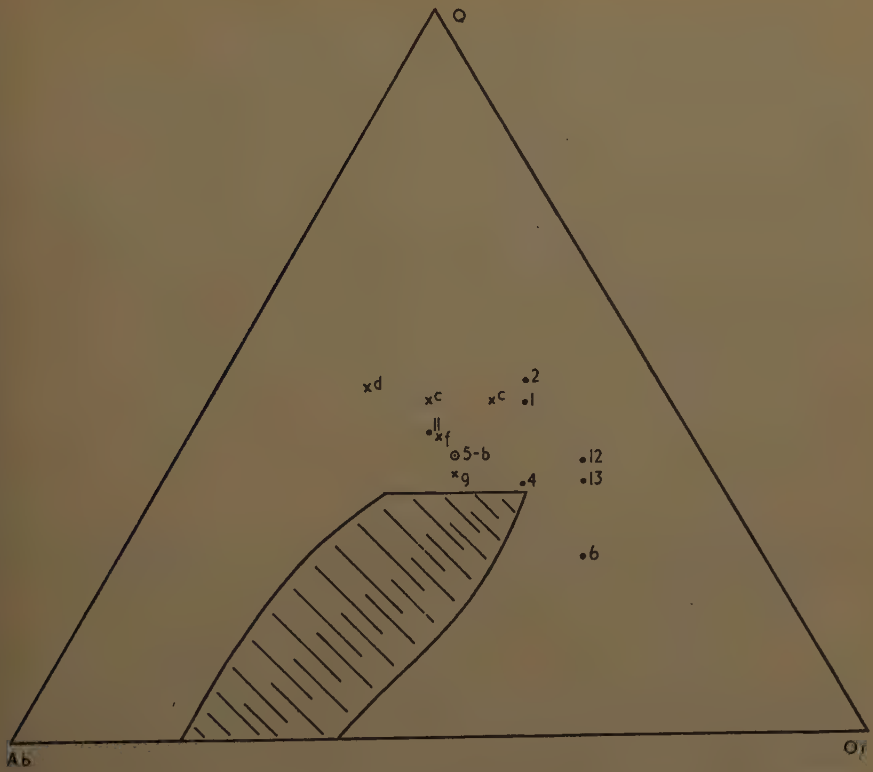

Fig. 7. Granodioritic rocks from Örsdalen plotted on «the residua system» of Bowen.

It is seen form fig. 7 that none of the examined specimens fall within the low temperature trough. The plotted points should be moved somewhat closer to the Q-Ab join as the amount of albite occurring in solid solution and as perthite lamellae within the orthoclase could not be calculated by the point counter method. This would perhaps leave point 6 within the trough.

As to the nature of the original rocks within the area nothing definite can be stated. The inclusions in the granodiorites are represented by amphibolites which show all transitions from well-defined inclusions with sharp contacts to just «ghostly remnants» in the gneisses. The latter are represented by an enrichment of femic minerals, usually biotite, within the gneisses and often show the same

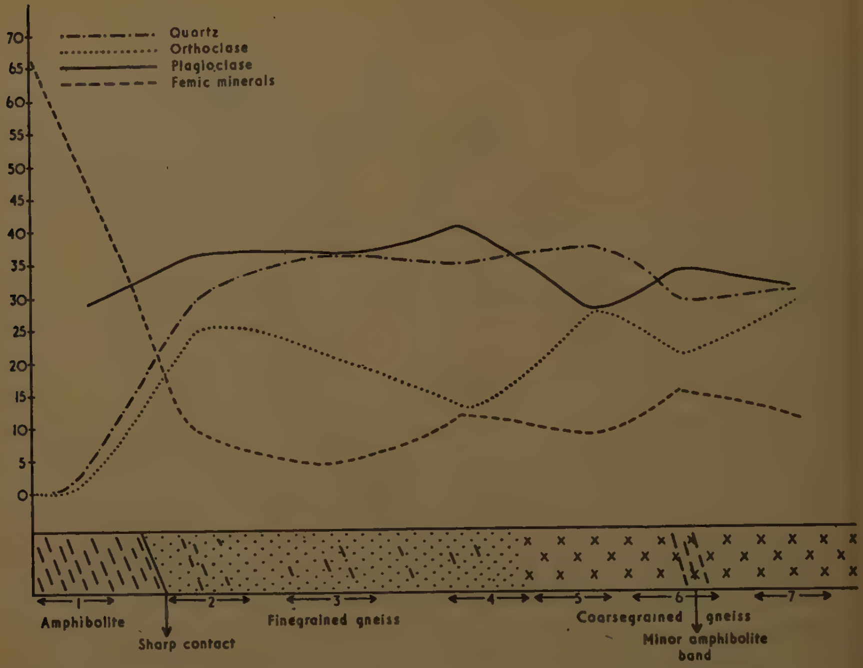

Fig. 8. Curves showing the mineral variations in a section of a diamond drill core.

lens shape as so commonly found for the less altered amphibolites and indicate the metasomatism to have been static.

Where the granodiorites have certainly originated through metasomatism of amphibolites no difference can be found in mineral composition between these and other granodiorites which give no clue as to their origin.

Even in cases where the amphibolites are seen to exhibit well-defined, sharp contacts against the granodiorites, this can be shown, by a closer examination in thin section, to be apparent rather than real.

Fig. 8 shows a section of a diamond drill core taken close to the mineralized zone in Örsdalen. An amphibolite is here seen to have a very sharp contact against a fine-grained granodioritic rock which after a while grades into a coarse-grained type. Dark bands representing remnants of amphibolites, are seen equally in the fine-grained and the coarse-grained granodiorite. Seven thin sections, marked a-g,

Table 5.

	a	b	c	d	e	f	g
	%	%	%	%	%	%	%
Quartz.....	4.3	29.2	36.0	34.8	37.0	29.0	30.0
Orthoclase perthite .	2.5	24.7	20.6	13.0	27.0	21.0	28.3
Plagioclase .	29.1An$_{38}$	36.5An$_{38}$	36.4An$_{38}$	40.5An$_{38}$	27.3An$_{36}$	33.4An$_{36}$	30.0An$_{36}$
Epidote ...	—	—	—	—	+	+	+?
Muscovite .	—	—	—	+	—	—	—
Hypersthene	4.8	1.5	0.7	—	—	—	—
Hornblende	35.4	—	0.4	1.8	—	10.6	—
Biotite	22.7	5.1	3.3	6.0	6.4	1.2	7.3
Chlorite ...	—	+	+	0.4	—	0.4	1.7
Iron Ore ..	1.2	3.0	2.6	3.5	2.3	3.4	2.0
Apatite	+	+	+	+	+	1.0	0.7
Sphene	—	+	—	—	+	+	—
Zircon	—	+	—	+	—	—	—

(+ indicates that the mineral occurs in very small amounts).

where made at small intervals along the core. The results of the thin section analyses are given in table 5 and the percentages of the minerals are plotted above the centre of the respective thin sections made in fig. 8. Section «a» was cut well on the amphibolite side of the sharp contact against the granodiorite but even so both quartz and potash feldspar are found in it. It is seen how the amount of femic minerals decreases quickly, later to show some maxima where dark bands occur within the gneiss. Compared with this it is of interest to study the curve showing the variations in the amount of potash feldspar. This curve is the mirror image of the curve for the femic minerals, indicating that potash feldspar to a large extent is replacing the femic minerals and not the plagioclase. The curve for the plagioclase does not show the same degree of variation but shows just minor maxima where dark bands occur in the gneiss. It is also of interest to note that the composition of the plagioclase is kept nearly constant all through the series, as seen from table 5. The curve for the quartz is similar to that for potash feldspar except that when the contact between the amphibolite and granodiorite is passed, it shows minor variations.

From this it can be inferred that the granitisation of the amphibolite mostly has the character of a replacement of the femic minerals by potash feldspar. In some thin sections it can be seen, however, how potash feldspar also replaces plagioclase (photo 5, pl. 3.), but this is not so general within this rock series as it was within the white gneisses.

It would be of some interest to get some idea of the element changes during the «granitisation». For this the calculation of the «Standard Cell» of BARTH (1948) could be used. Without any chemical analyses this calculation cannot be very exact, but a half-quantitative expression can be obtained by calculating the cation % of the thin section analyses of table 5. In table 6 examples a and g are compared in this way.

Table 6.

	Cation %	
	a	g
SiO_2	45.2	66.0
$AlO_{1\frac{1}{2}}$	15.7	15.0
$FeO_{1\frac{1}{2}}$	0.8	1.3
(Fe, Mg) O	19.6	3.7
CaO	6.3	2.4
$NaO_{\frac{1}{2}}$	4.7	3.7
$KO_{\frac{1}{2}}$	3.0	6.5
H_2O	4.7	1.4
	100.0	100.0

«Standard Cell»

a $K_{3\cdot 2}\ Na_{4\cdot 8}\ Ca_{6\cdot 7}\ (MgFe)_{21\cdot 0}\ Fe^{3}_{0.8}\ Al_{16\cdot 7}\ Si_{48\cdot 5}\ (O_{150\cdot 6}\ (OH)_{9\cdot 4})$
g $K_{6\cdot 2}\ N_{13\cdot 6}\ Ca_{2\cdot 2}\ (MgFe)_{3\cdot 6}\ Fe^{3}_{1.3}\ Al_{14\cdot 3}\ Si_{62\cdot 5}\ (O_{157\cdot 4}\ (OH_{2\cdot 6})$
By the metasomatism we have

brought in:	3.0 (1.8) K ions	carried out	1.2 (0) Na ions
	0.5 Fe^3 «		4.5 Ca «
	14.0 Si^4 «		17.4 (MgFe) «
			2.4 Al
			6.8 H
	17.5 cations		32.3 cations
corresponding to:	60.5 valences		59.0 valences

It should be added that the amount of sodium in solid solution and as exsolved albite lamellae in the potash feldspar cannot be accounted for in this way. A chemical analysis made of the potash feldspar of an augengneiss occurring some 100 meters away gave the following molar ratio of the feldspar components present: $Or_{68,9}$ $Ab_{30,0}$, $An_{1,1}$. Assuming this ratio to be the same in our example it would mean that the amount of sodium is kept nearly constant and the amount of introduced potassium will be a little less than 2 cat.%.

The main substance introduced during the metasomatism will be silica and not potassium, and the main elements leaving the rocks will be the femic ones.

An important question is what was the regional PT conditions prevailing during the metasomatism. The metamorphism of the area will be treated in the next chapter and it will then be shown that even in parts which today are found in a very low metamorphic facies, relicts of high metamorphic minerals are found showing that even these once have been in a high metamorphic state. The highest regional metamorphism found corresponds to the PT conditions of the lower part of granulite facies, and it is assumed that this was the PT conditions during which the metasomatism of the area took place. In favour of this is the above cited chemical analysis of the potash feldspar. The plagioclase in this rock is of the composition An_{30}. Using the coefficient of distribution of Na between the two feldspar phases as calibrated by Barth (1951) this will give a temperature of formation for this feldspar of about 650° C or within the temperature limit usually assigned to granulite facies.

THE METAMORPHISM

During the petrological discussion of the rocks it was pointed out that the same types of rocks exhibit different mineral facies according to their location within the area. A discussion of the metamorphic facies found and how they are grouped in the field will now be separately attempted.

For a classification of the rocks into different metamorphic facies intervals it has been common to use some minerals or mineral-combinations which are supposed to be critical for different PT intervals.

The femic minerals are used by ESKOLA (1921) as key minerals in the metamorphic classification of rocks. These are, however, highly dependent upon the water vapor pressure and YODER (1952) has given the experimental proof for the necessity in regarding water on a line with the other element oxides in a PTX system. He finds that at around 500° C all the femic minerals will be stable within different water vapor pressure intervals.

The femic minerals within the area show the transitions chlorite — biotite — mon. hornblende — mon. pyroxene — rhomb. pyroxene. The classical facies diagrams show that chlorite will not be stable above the epidote amphibolite facies. In Örsdalen chlorite is found in places where the metamorphism is so low that of the other femic minerals not even biotite is stable. It is also found, however, in rocks where the other minerals define an amphibolite facies. Hypersthene is, however, never found as a stable mineral when chlorite occurs. That chlorite is stable in amphibolite facies agrees with the findings of other authors. BUGGE (1943) discusses it from the Arendal region in S. Norway and RAMBERG (1952) assumes it to be true under certain circumstances. Not long ago SEITSAARI (1954) discussed a paragenesis of bytownite, chlorite and Mn.-garnet from Kangasala in Finland and concluded that it must be classified as belonging to amphibolite facies.

According to this it must be concluded that chlorite does not exclude a classification of rocks in amphibolite facies.

The occurrence of diopside is supposed by Ramberg to define the transition epidote amphibolite — amphibolite facies while rhombic pyroxene is critical for the higher part of amphibolite facies.

Garnets are common femic minerals in regional metamorphic rocks and according to the usual facies diagrams they are stable from the lower part of epidote amphibolite facies and upwards. The mere statement that garnets occur in a rock does not therefore tell much about the metamorphism, and they must first be seen in relation to the other minerals occuring. It has, however, for a rather long time been understood that the composition of a garnet will be dependent upon the PT conditions during its formation, in such a way that the low metamorphic garnets should be rich in manganese, while the granulite or eclogite garnets should have more of a pyrope composition. As early as in 1920 GOLDSCHMIDT (1920) wrote: «Bei

Diskussionen über Granat im Tonschiefer-Derivaten muss man übrigens stets berücksichtigen, dass hier zwei Arten von Granat vorkommen, nähmlich in meist geringer Menge als erste Bildung ein Spessartin — Almandin, der erst bei zunehmenden Grade der Metamorphose von Almandin überflügelt wird».

Goldschmidt separates two types of garnets, but as shown by MENZER (1929) we can regard the common regional metamorphic garnets as formed by a gradual substitution of Mn^{2+} and Mg^{2+} in the crystal lattice. It is possible to distinguish between two distinct types of garnets the one being the calcium-rich grandites, and the other the calcium-poor pyralspites. Between these very little substitution takes place and it is the pyralspites which are usually found in regional metamorphic rocks.

On this basis MIYASHIRO (1953) has been able to construct a three-component diagram showing the variations of the Mn^{2+}, Fe^{2+} and Mg^{2+} content in garnets according to the metamorphic grade. The diagram is empirically founded and therefore corresponds to natural conditions.

Some chemical analyses of garnets from different localities within the Örsdalen district were carried out on my behalf by the chemical laboratories of A/S Norsk Bergverk at Söve. They are plotted on the diagram of Miyashiro and reproduced here as fig. 9. The results seem to correspond very well with the idea of the metamorphic grade which could be deduced in other ways. The chemical analyses are given in table 7. For a further check the specific gravities and the size of the unit cells were also determined. (The sp.G. was determined after the chemical analyses were carried out and in some cases too little material was left for this purpose.) Only the total iron was determined, partly because the content of the three valent iron is known to be small in this kind of garnets, but mainly because of the difficulties in determining bivalent iron in garnets.

It will be seen from the table that the unit cell size of no. 8 indicates a higher spessartite content in this garnet than is derived from the chemical analyses. The sample is from a small high metamorphic area in Gyadalen where the amphibolites contain the minerals: plagioclase (labradorite or andesine), hypersthene ± diopside and hornblende ± biotite. White gneisses occur together with these and the high metamorphic sample 1 from table 3 is taken here. The

Table 7.

Analyses	1	2	3	4	5	6	7	8
	weight %	weight %	weight %	weight %	weight %	weight %	weight %	weight %
SiO_2	35.96	35.79	36.70	36.70	37.20	37.30	36.80	35.30
Al_2O_3 ...	20.33	21.55	21.50	21.20	23.30	21.37	21.70	22.52
FeO	34.42	30.80	34.84	31.77	27.40	29.02	29.50	31.2
MnO ...	2.35	5.05	1.63	0.80	0.64	1.05	3.80	0.95
MgO ...	4.13	2.80	4.10	7.13	9.33	8.82	6.33	9.00
CaO	2.35	3.48	2.20	1.92	1.26	1.26	1.87	1.03
	99.54	99.47	100.97	99.52	99.13	98.82	100.00	99.92

(TiO_2 is reported present in some of the samples in an amount of 0.1 %)

	Cat. %	(foot-note)	Cat. %	(foot-note)	Cat. %	(foot-note)	Cat. %	(foot-note)	Cat. %	(foot note)	Cat. %	(foot note)	Cat. %	(foot note)	Cat. %	(foot note)
SiO_2	36.2	37.5	36.2	37.5	36.4	37.5	36.2	37.3	36.0	37.4	36.6	36.3	36.2	36.7	34.2	37.5
$AlO_{1\frac{1}{2}}$ ...	24.1	25.0	25.6	25.0	25.1	24.9	24.5	25.1	26.6	25.1	24.7	24.9	25.1	25.1	25.7	25.0
FeO	29.0	26.4	25.9	25.5	28.8	27.9	26.0	24.0	22.1	22.2	23.7	23.7	24.2	23.6	25.1	22.8
MnO ...	2.0	2.1	4.3	4.2	1.4	1.5	0.7	0.7	0.5	0.5	0.8	0.9	3.2	3.3	0.8	0.7
MgO ...	6.2	6.3	4.2	4.2	6.1	6.0	10.6	10.8	13.5	13.5	12.9	12.9	9.3	9.3	13.1	12.9
CaO	2.5	2.7	3.8	3.6	2.2	2.2	2.0	2.1	1.3	1.3	1.3	1.3	2.0	2.0	1.1	1.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 7 cont.

Sp. G. . . .	4.065	4.069		3.963	3.967	3.975	3.331 ?	3.357 ?
refractive index . . .	1.800 ±0.001	1.802 ±0.001	1.800	1.792 ±0.002	1.787 ±0.001	1.779 ±0.005	1.783	1.783
unit cell.	*11.55*	*11.57*	*11.54*	*11.54*	*11.51*	*11.53*	*11.53*	*11.54*
	Mol %	Mol %	Mol %	Mol %	Mol %	Mol %	Mol %	Mol %
alm.	70.44	67.8	74.6	64.0	59.1	59.5	61.7	60.8
spes, . . .	5.52	11.3	3.6	1.9	1.3	2.2	8.5	2.1
py	17.11	11.0	16.0	28.6	36.1	34.7	24.6	34.2
gr.	6.94	9.9	5.8	5.4	3.5	3.6	5.2	2.9
alm.	75.70	75.3	79.5	67.7	61.2	61,7	65.0	62.5
spes. . . .	5.90	12.5	3.9	2.0	1.4	2.3	9.0	2.3
py.	18.40	12.2	16.6	30.3	37.4	36.0	26.0	35.2

[1] Amount of cations used for obtaining the garnet composition listed below.

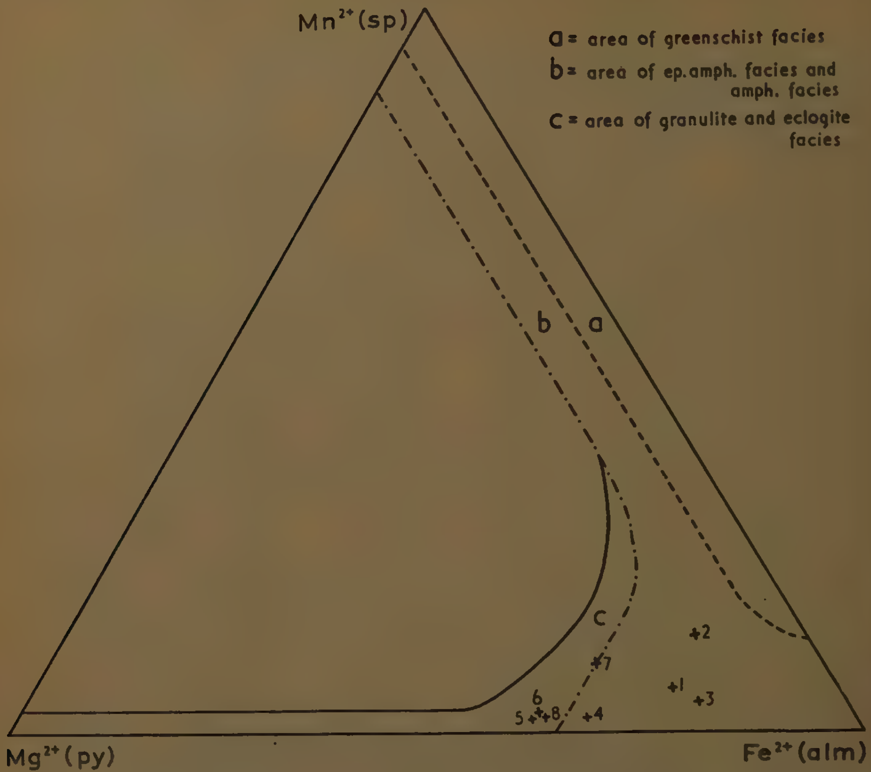

Fig. 9. Analysed garnets from the Örsdalen district plotted on the diagram of Miyashiro.

chemical analyses do therefore seem to place the garnet within the correct metamorphic facies, and the mineral does not seem to be altered when studied under the microscope. The facies transitions within this part of the area are, however, very rapid and the white gneisses are known just a very short distance away to belong to the epidote — amphibolite facies. (In fact within the same hand specimen we may have minerals corresponding to granulite facies on the one side while a very low metamorphism prevails on the other). A possible error in the chemical analyses can therefore not be neglected. The localities of the analysed garnets are plotted with corresponding numbers on the map. fig. 10.

A classification of rocks into different facies areas in the field based on variations in the femic minerals alone is difficult in a region where acid quartz-feldspar gneisses form the greater part of the outcrops. In these rocks biotite is often the only femic mineral and this may be stable over a large facies interval. The garnets may be used for a classification of the white gneisses, but then their composition must first be known either by a chemical analysis or by a determination of so many variables that their composition can be deduced, which is a rather troublesome task. For these rocks it is therefore important to find a way of classification built upon the variations in feldspar minerals.

Ramberg (1952) uses the equilibrium plagioclase (An_{30}) $\rightleftarrows$ zoisite as a definition of the lower part of amphibolite facies and this reaction may be used with great advantage for the acid rocks in Örsdalen. The plagioclase in these rocks, when more acid than andesine, is usually saussuritized and in equilibrium with zoisite showing that they have primary been of a more basic composition. To separate areas in amphibolite facies from the lower facies is therefore not very difficult.

Rosenqvist (1952) has shown how the form and orientation of alkali feldspar perthites can be used in a facies classification. Because of the nature of the metamorphism in Örsdalen I have not been able to make use of this considerations.

As mentioned in the petrographical part of this paper potash feldspar is found both in the moneclinic form, orthoclase, and in the triclinic, microcline. Where it has been possible to be certain, it has turned out that orthoclase is never found in rocks where the metamorphism is lower than amphibolite facies, while microcline is the alkali feldspar in these rocks and also in the lower part of amphibolite facies. This is in good agreement with the experiments of Goldsmith and Laves (1954) who find that the transition from the triclinic to the monoclinic form takes place at around 500° C under hydrothermal conditions.

The map, fig. 10, shows the metamorphic situation of the area. The classical facies classification is only partly used and instead different facies are regarded together and the whole range from greenschist to granulite facies is divided into three groups.

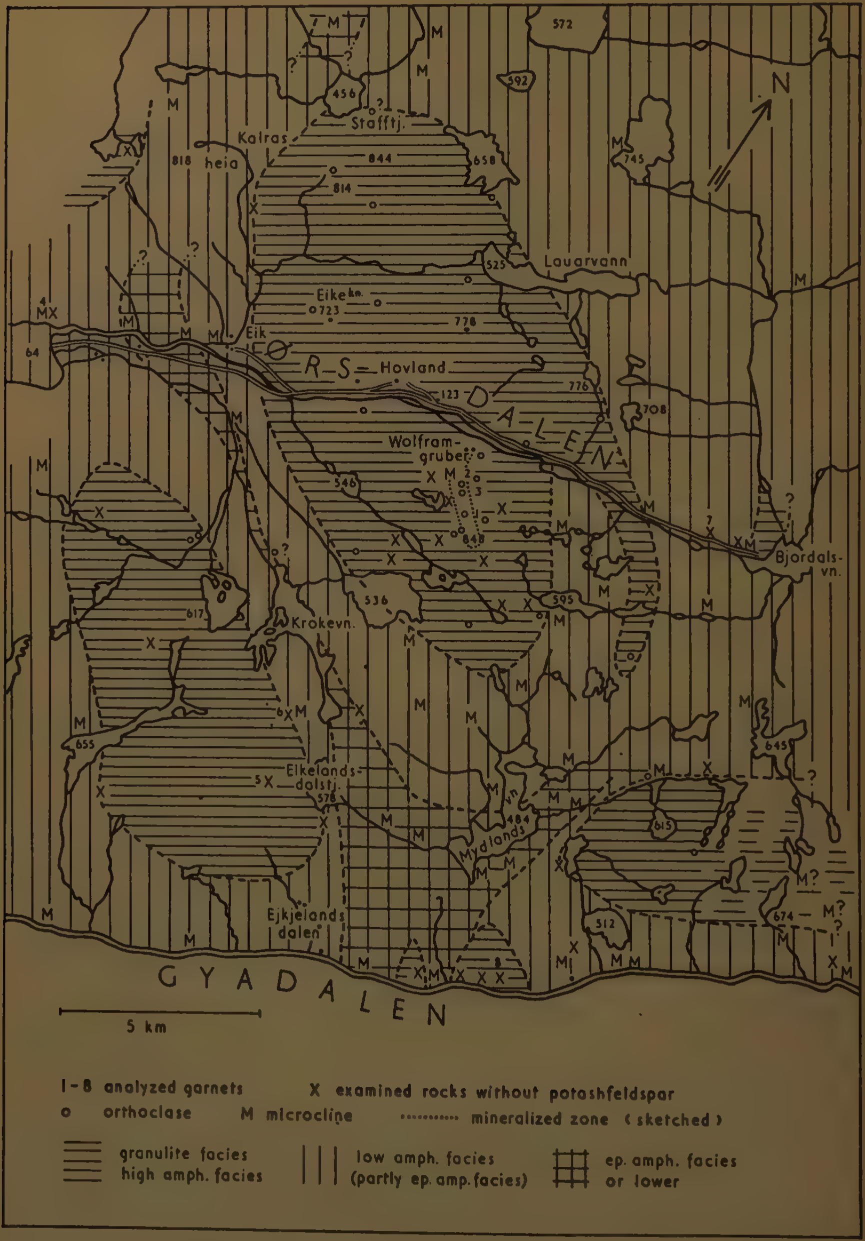

Fig. 10. Map showing the variations in metamorphism within the Örsdalen district.

These are:

1. high amphibolite facies (granulite facies to the higher part of amphibolite facies).
2. low amphibolite facies
3. epidote amphibolite facies or lower.

This is done because a division like this gives a good picture of the metamorphic situation of the area. Further it can be based mainly upon the variations in the minerals of the quartz-feldspar gneisses. For these rocks the division has been shown to be critical for the mineral transitions as follows:

high amph. facies — low amph. facies — ep. amph. facies
orthoclase $\rightleftarrows$ microcline, plag. (An_{30}) $\rightleftarrows$ zoisite

In the high metamorphic facies the plagioclase can in some places be of an oligoclase composition, but it is then never secondarily altered into zoisite, while in the low metamorphic areas the plagioclase is always heavily saussuritized and chlorite and sometimes biotite, is the common femic mineral.

Fig. 10 shows three high metamorphic areas of some extension and two smaller ones in Gyadalen and one in the upper north-west corner of the map.

The rocks within the area to the west show mineral combinations which would classify them as belonging to the granulite facies in the ordinary meaning of this name. Hypersthene is a common mineral as well in the amphibolites as in the gneisses, and the potash feldspar is of course always an orthoclase. Rocks resembling the plag. rich type of the white gneisses occur here with the only difference that they contain hypersthene instead of garnets. The garnets no. 5 and 6 are from this place and their composition corresponds to what should be expected in a mineral paragenesis like this.

The central part of the map. fig. 10 represents the largest area in high amphibolite facies and it was mainly because of the conditions here that the granulite and the higher part of amphibolite facies was regarded together and separated from a lower amphibolite facies. In some places hypersthene and hornblende ± diopside occur together in the amphibolites which therefore may be classified as belonging to granulite facies, but in other places hypersthene is lacking or it is only found as relics in a high degree of alteration. In these rocks hornblende and biotite ± diopside represent the femic minerals. Hypersthene may also occur in the granodiorites, but hornblende and biotite is much more common. The plagioclase is, however, always an andesine and the alkali feldspar an orthoclase.

In some places within this area and in close connection with the mineralized zones the rocks are found in a much lower state of metamorphism. These are, however, highly local and not many metres to the sides hypersthene is again stable in the gneisses. The lower metamorphism within these zones is also indicated by the garnets no. 1, 2, 3 on fig. 9 which all are found in connection with the mineralized part.

The high metamorphic area in the south-east part of the map is not of any considerable extension compared with the other two and in the eastern part it shows transitions towards low amphibolite facies.

Two smaller high metamorphic areas are separated in Gyadalen and one in the upper north-west corner of the map.

The areas previously discussed are surrounded on all sides by rocks in a low amphibolite facies. An exception is the two small areas in Gyadalen which are partly surrounded by very low metamorphic rocks.

The areas in low amphibolite facies mainly consist of quartz-feldspar gneisses while amphibolites are more rare. It follows therefore that the metamorphic classification must mainly be based upon the former. The alkali feldspar is here always a microcline and the plagioclase an andesine but may grade into an oligoclase composition and is usually somewhat saussuritized. The characteristic minerals in the gneisses are: quartz, microcline, plagioclase ± zoisite, biotite, hornblende and chlorite. The white gneisses also often contain garnets and the garnets no. 4 and 7 on fig. 9 are connected with these rocks.

Rocks in a low metamorphic state can be traced from Gyadalen up between the lakes Mydlandsvann and Ejkelandsdalstjern. From here they separate into two arms, one of which passes across Krokevann, where it is very narrow, and widens out again towards Örsdalen. From here it is possible that it turns into a more northerly direction and is connected with the low metamorphic part north of Stafftjern. The other arm turns north-east from Mydlandsvann and may be connected with similar rocks at Bjordal. The metamorphic facies within these parts are greenschist and low epidote amphibolite facies, but towards the borders high epidote amphibolite facies is also found. Pressed white gneisses with amphibolitic bands constitute the rocks within these parts and the characteristic mineral content is: quartz, microcline (sometimes sericitized) albite, zoisite, chlorite and sometimes biotite. Garnets are frequent within the white gneisses. Minor quartz stringers with chlorite and epidote which are seen to cut through all the other minerals in the rocks are frequently met with here.

DISCUSSION OF THE NATURE OF THE METAMORPHISM IN ÖRSDALEN

It is evident that the low metamorphic rocks found in Örsdalen are products of a retrograde metamorphism and that the rocks in granulite — and high amphibolite facies are found in areas which for some reasons have been left undisturbed by these late processes. The secondary nature of the low metamorphic rocks are traced in their minerals as the saussuritisation of the plagioclase, the sericitisation of the microcline and the fact that other high metamorphic minerals, as for instance hypersthene, are found as relics in them.

It seems further correct to assume that the retrograde metamorphism is influenced by penetrating solutions which are traced in the secondary quartz — chlorite — epidote veins cutting through the other minerals and which are only found in the low metamorphic rocks.

It was previously mentioned that the rocks in immediate contact with the mineralized zones in Örsdalen often are found in a lower metamorphic facies than corresponding rocks some metres away. This is of course a feature generally known in connection with orebodies. Secondary processes, probably of the nature of hydrothermal activity, can be traced, however, within the ore minerals themselves where they have resulted in the formation of scheelite as an alteration product of wolframite. This feature has been described earlier in more detail by the author (1955a) and it is natural to connect it with the retrograde metamorphism which has taken place in other parts of the area.

The rapid transitions from high to low metamorphic areas, which cannot be ascribed to offsettings, and the fact that within the latter the amphibolites in many cases contain their primary high metamorphic minerals while the surrounding white gneisses have undergone a complete alteration, shows that the metamorphic variations cannot be ascribed to differences in the regional PT relations. Petrological problems are usually discussed in terms of variations in a physico-chemical PTX system where P is identified with the general rock pressure, T with the temperature and X is the chemical composition of the system. The same values of both P and T must be ascribed the whole field examined. As regards X, the fact that the white gneisses are typical for the low metamorphic areas might be considered important. They are, however, not radically different from the granodiorites and alkali feldspar and plagioclase are together with quartz by far the most important minerals in them both. Besides, the white gneisses are known to exist in different metamorphic facies and low metamorphic granodiorites are also found.

The clue to the problem must be found in the tectonics of the area. When comparing the structures on the attached map with fig. 10 some interesting features become evident.

It is seen how the central high metamorphic area corresponds very closely to the rocks within the elongated basin fold, and how the low metamorphic parts are represented by the strongly pressed rocks which merge around the fold on both sides of it. These latter represent what is believed to be tectonical zones of weakness in some way connected with the folding.

As mentioned earlier the evidence is that the rocks in Örsdalen were in a plastic state during the folding and that the recrystallisation and metasomatic processes are synkinematic. Within the low metamorphic zones the rock minerals are seen to be fractured and the fractures are sometimes filled by the secondary quartz — chlorite — epidote veins. This might mean that these rocks were not reacting to the pressure in a plastic way or that late movements have taken place here. Though fractured the rock minerals cannot be said to be crushed or brecciated and the foliation is always conformable with that of the rocks within the high metamorphic parts. The general picture is more of an opening of fractures during a release of pressure.

It seems reasonable therefore, to assume that the low-metamorphic rocks represent zones of intense squeezing between more rigid rock bodies. These rocks were then brought into a high energy state which alone might be responsible for the mineral equilibria found here.

The secondary quartz veins must, however, have been introduced at a later stage, after the opening of the fractures, and the theory outlined above would regard these apart from the retrograde metamorphism. The author has therefore adopted the following theory.

After the folding which resulted in the intense squeezing of rocks within certain zones and which took place in the katazone of the earth (corresponding to the PT conditions of granulite facies), a regional uplift took place. As the pressure conditions became different, the squeezed rocks, which now were completely crystalline and rigid, were able to expand and became fractured. Existing solutions were then able to penetrate these rocks more easily, following the fractures as channelways, than they were in the rocks at the sides where only the grain surfaces could act as channels. Regarding now the elements of the solutions, mostly water, on a line with the elements constituting the rock minerals the X conditions in the PTX system would become different and mineral reactions could take place which were not possible within the rocks at the sides. The same solutions are believed to be responsible for the metasomatic alteration of wolframite into scheelite as the mineralized zones themselves would here act as open channels.

The local character of the retrograde metamorphism is nicely illustrated by the following example.

In one of the crosscuts close to the opening of tunnel 1 along the mineralized zone in Örsdalen the rocks consist of a grey high metamorphic granodiorite of the ordinary type (a, table 8). Within this rock a zone about 3 m wide occurs where the rocks are found in a low metamorphic state (b, table 8). The potash feldspar of this rock is reddish and the plagioclase greenish because of the alteration into zoisite. As a whole this rock is similar to the low metamorphic granodiorites found at other places within the area.

The mineral percentages indicated in the table are determined by point-counter, but as the rocks are coarse-grained this method cannot claim any high degree of accuracy and too much weight should not be put upon the percentage differences. As a whole the two rocks are believed to be closely similar as regards chemistry.

Table 8.

	a %	b %
Quartz	34.6	31.2
Orthoclase	26.6	—
Microcline	—	43.4
Plagioclase	32.4	22.3
Hypersthene	0.6	—
Hornblende	3.4	—
Biotite	0.7	tr.
Muscovite	—	tr.
Chlorite	—	3.1
Iron ore	1.4	0.1
Apatite	0.3	tr.

It is the type of minerals occurring which is of interest. In rock a. the femic minerals are hornblende, hypersthene and biotite, while chlorite is dominent in rock b. While the plagioclase in a. is fresh and of the composition An_{36} which is the common plagioclase composition for the unaltered granodiorites within the field, it is in b. highly saussuritized and it is not possible to dertermine the composition but it is probably albitic. In both samples some of the plagioclases are antiperthites with rather large potash feldspar lamellae.

While in a. the potash feldspar is an orthoclase perthite it is a microcline perthite in b. showing well developed microcline cross hatching. The potash feldspar of three feldspars within the low metamorphic zone were examined by X-ray, and the triclinicity (GOLDSMITH and LAVES 1954) was determined as 0.87 for all of them. Samples which were taken just about 50 cm away on both sides were by the same method proved to contain the monoclinic form orthoclase.

This shows the local character of the retrograde metamorphism and the impossibility of ascribing it to pressure and temperature differences, since these should be characterized by gradual mineral transitions. A sufficient water pressure within certain zones will, however, favour the formation of hydroxyl-containing femic minerals as experimentally shown by YODER (1952). As the saussuritisation of plagioclases also involves the action of water the same can be stated for this mineral transition.

As regards the symmetry transitions for the potash feldspar, the work by GOLDSMITH and LAVES (1954) has proved the catalytic influence of water also for this reaction.

It must therefore be concluded that some time after the crystallisation of the rocks in granulite facies the rocks within certain zones were penetrated by water solutions which transformed the existing minerals into minerals in equilibrium with the amount of water at a certain PT level. The point to be stressed is that the same PT conditions must be ascribed to the field as a whole, but because of a lower water pressure the high metamorphic mineral paragenesis was here still in equilibrium.

THE RELATIONS BETWEEN THE DEEP-SEATED ROCKS OF THE EGERSUND AND TELEMARK FORMATIONS

Both the Egersund and Telemark formations represent huge areas of deep-seated rocks, the distance between the central parts of which is about 160 km in a NE direction. (Strictly speaking the Telemark formation is in Norwegian geology a name held for the important complex of mainly quartzites and acid lavas overlying the deep-seated rocks here considered). The Egersund suite consists of anorthosites, norites and monzonitic rocks formed in the catazone of the earth crust under PT conditions corresponding to granulite facies which also is the metamorphic facies these rocks exhibit today. The deep-seated rocks in the Telemark formation are on the other hand represented by granites and gneiss granites, with amphibolitic bands and lenses occurring in the latter. The former must be believed to have been formed in the middle mesozone (epidote amphibolite facies), but the metamorphism of the rocks tends to increase in a south-west direction approaching the Egersund area, which would indicate increasing depth of rock formation in the same direction. Very little geological work has, however, been done between the centres of the two formations.

As to the age relations between the two formations very little is published. The question has, however, been up in discussion between Norwegian geologists during several years and they have generally been considered as two distinctly separated formations.

Regarding the geological map of the western part of Sörlandet by BARTH (1954) it is, however, evident that the transitions between the two are gradual with anorthositic bands occurring inside the gneisses and vice verca. The Örsdalen region represents in many ways a border zone between the two formations in question and it would be of interst to discuss the age relations on a basis of the geology found here.

Except for the young diabase dyke it is difficult to state anything definite about the relative age of the rocks within the district. The amphibolites do obviously represent the oldest rocks exposed as they occur as lenses and relics in both the granodioritic and white gneisses. The age relations betwen the latter are, however, more intricate and they may well be contemporaneous. They have both been subjected to the same kind of orogenic forces and metasomatic processes have been important for the formation of both.

The pre-metasomatic composition of the two rocks is not definitely known. The evidence for the formation of the white gneisses point towards a primary anorthositic composition for these rocks. (That this is so is not definitely proved and it is of interest to note that SÖRENSEN (1955) who has seen samples of the rocks in question, states that rocks of a similar appearance occur in granulite facies areas on Greenland where they are named granulites).

The metasomatic processes are of the nature of granitisation and it seems appropriate to connect them in time with the formation of the Telemark granite which would mean a relatively young age of this rock. The occurrence of molybdenite and tungsten minerals within the granodiorite point the same way. These are believed to belong to a late stage of the granitisation and the rock foliation must already have been developed when the mineralisation took place (HEIER 1955a). Örsdalen is the only Norwegian locality for wolframite, but both molybdenite and scheelite are characteristic minerals in the different ore bodies associated with the Telemark granite.

Based on these facts all the evidence is that the Egersund suite of rocks represents the oldest formation and the belief expressed by ADAMSON and NEUMANN (1952) seems justified. They state: «As to the age of the Ekersund formation which consists of anorthositic and charnockitic rocks, no definite statement can be made. In the opinion for the authors it may well be older than the other two». (Referring to the Kongsberg-Bamble and the Telemark formations.)

Though there is no evidence for the Egersund suite to be the younger of the two, the possibility of a contemporaneous formation at different depth must not be neglected and this would in fact be in accordance with the evidence presented above.

The Egersund kind of rocks are typical for the deeper parts of the earth crust (katazone) while the processes producing granites have a sufficient rate of reaction already in the middle mesozone (SKJESETH and SØRENSEN 1953). As stressed earlier the typical Telemark granite is found in epidote amphibolite facies which corresponds to the depth level of middle mesozone. Turning south-west the rocks are found in an increasing degree of metamorphism corresponding to gradually increasing depth levels exposed. At Örsdalen the primary metamorphism has reached the boundary between amphibolite and granulite facies and we are no longer dealing with granites, but the more calcic variety, granodiorites. Proceeding into the Egersund formation the mineral associations found are typical for granulite facies.

Even if the Egersund rocks originally belonged to the geosyncline basement of the Telemark orogenesis they are found as a member of an unbroken sequence of increasing depth levels exposed in the direction NE — SW as is indicated by the variations in the regional metamorphism. Thus they must have been subjected to the whole process of magmatism, metasomatism and metamorphism characteristic for the deeper parts of geosynclines, and have been completely recrystallized during the Telemark orogenesis.

It thus seems impossible to escape the conclusion that the Telemark and Egersund rocks represent contemporaneous formations, and while the former corresponds to a layer where alkali minerals are stable, the latter is representative of depth levels where these tend to break up.

Acknowledgements.

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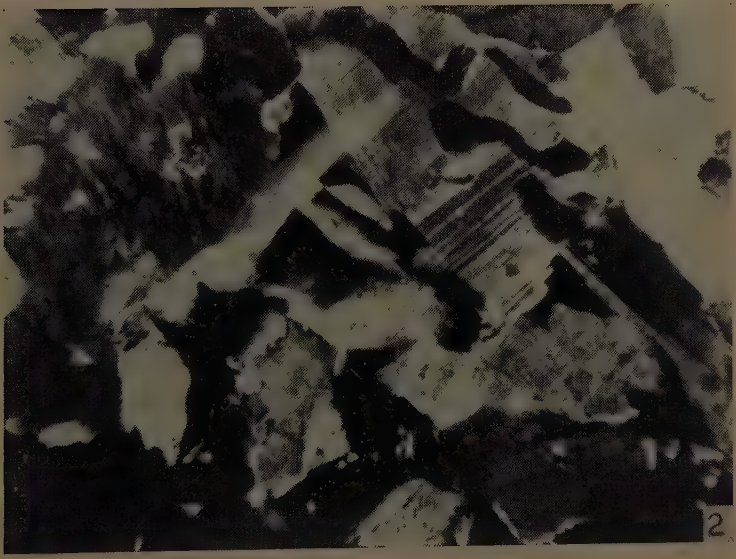
I also want to express my sincere thanks to my professors and teachers at the University of Oslo and especially to professor Dr.

PLATES I–IV

PLATE I

1. Typical «mesoperthites» from Örsdalen.
2. Veins of potash feldspar (black) replacing plagioclase.

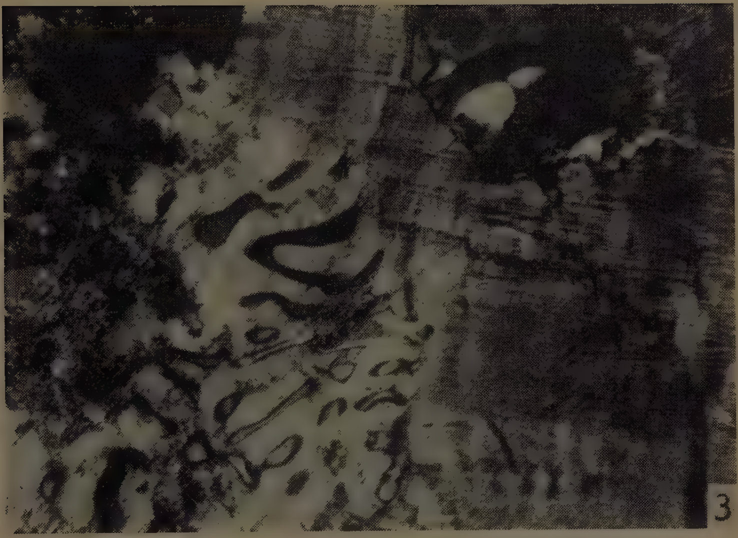
1



2

PLATE II

3. Myrmekite quartz spindles in plagioclase along the contact against microcline.
4. Rutile needles in quartz showing sagenite structures.



3

4

PLATE III

5. Myrmekite quartz spindles within plagioclase inclusions in orthoclase perthite.
6. Hornblende contacting heavily altered hypersthene.

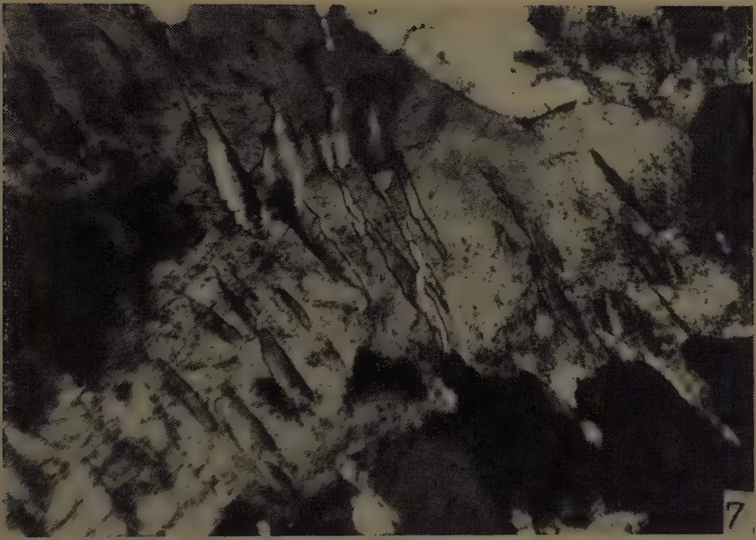
5

6

PLATE IV

7. Replacement of plagioclace by potash feldspar. The microcline individual on the right side of the photo is seen to cross the contact between two plagioclases.

8. Antiperthite in the white gneisses of the same type as those occuring within the anorthosites of the Egersund region.



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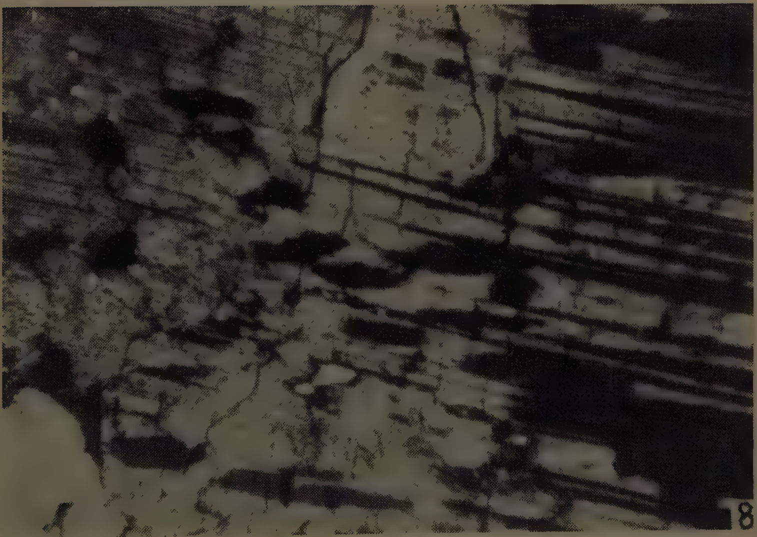

8

PEGMATITE VEINS AND THE SURROUNDING ROCKS

I. Petrography and structure.

By

PAUL REITAN

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Abstract: A very detailed map of the island St. Hansholmen, Risør, southern Norway, is presented. The rock type on the island is the banded gneiss common along the south coast. It consists of alternating bands of gneiss and amphibolite with pegmatite veins and inter-boudin fillings confined to the amphibolite bands.

The amphibolite usually consists almost wholly of hornblende and plagioclase. The gneiss consists of plagioclase, quartz, sometimes microcline, with small amounts of biotite and magnetite. The plagioclase in both the amphibolite and gneiss lies in the range An_{36} to An_{27}, average An_{31}. The pegmatites are of three types. On the west end of the island there is a pink, microcline rich pegmatite vein which cross-cuts both the amphibolite and gneiss. Confined to the amphibolite bands there occur white pegmatites containing plagioclase An_{30} and, as fillings between boundins, there occur white pegmatites containing plagioclase An_{23}.

The structural elements of the island, contacts and foliation of the gneiss, are nearly vertical and strike ca. EW to WSW. A sharp, almost isoclinal fold is revealed on the island.

The pegmatite veins, confined to the amphibolite bands, tend to follow two directions with one of these dominant on both limbs of the fold. Postulating that the fold revealed on St. Hansholmen is a minor fold on the limb of a larger fold, this fact, along with the development of boudinage structure in the amphibolite and the occurence of pegmatite fillings between boudins, is explained as being due to differences in rigidity between the amphibolite and the gneiss during the dynamo-thermal metamorphism of the area.

Three posssible modes of origin for the pegmatites are discussed. They can be characterized as; (1) magmatic, (2) hydrothermal, and (3) by metamorphic differentiation. The conclusion is reached that the plagioclase pegmatite veins and pegmatite fillings between boudins can best be explained as the result of crystallization from a dispersed phase which diffused intergranularly towards the low pressure areas which arose during the deformation of the area. The alkali content of the feldspars in the surrounding gneiss indicates that the temperature of the environment in which these pegmatites formed was well below the range of magmatic temperatures. The suggestions offered account for the location, composition variations and relative grain size of the plagioclase pegmatites.

Very little can be said about the genesis of the pink microcline rich pegmatite which crosses the western tip of St. Hansholmen, on the basis of the present study.

The spacial variation in the microcline content of the gneiss may be interpreted such that it supports the genesis by metamorphic differentiation which has been suggested for the banded gneiss.

Introduction.

This paper is the first part of a study concerned with pegmatite veins and their relations to the surrounding rocks. The word pegmatite is used as a textural term without mineralogical implications.

The problem herein considered is that of the physical factors which control the localization of pegmatite material and, along with this, petrographic variations in the pegmatites and the surrounding rocks and their significance.

To begin this study an appropriate area of completely exposed rocks containing pegmatites was chosen for very detailed mapping. The island of St. Hansholmen, lying just outside of Risør on the south coast of Norway, was found to be satisfactory with the exception of the northwestern part which was mostly covered and therefore not mapped. The mapping was done during the autumn, 1955, and spring, 1956, at the scale 1:200, using tape and compass. The map is presented here at the scale 1 : 600. The island is located in the southern part of the Kongsberg-Bamble formation and consists of the banded gneiss common along Norway's south coast in this area. The rocks are all pre-Cambrian and are part of the roots of an ancient mountain range. The metamorphic facies represented on St. Hansholmen is the amphibolite facies.

There has been considerable study of the southern part of the Kongsberg-Bamble formation and of particular areas and problems presented by the rocks therein. Studies in the area were begun as early as 1857 by an Englishman, Robert Forbes (19). Rather than summarize the results of previous investigations in the region here, in an attempt to place the area studied in its geologic setting, reference is made to the original works of O. Andersen (1), (2); T. F. W. Barth (3); H. Bjørlykke (6), (7), (8); W. C. Brøgger (9), (10), (11); A. Bugge (12), (13), (14), (15), (16); J. A. W. Bugge (17), (18); J. C. Green (22); B. Hofseth (23); O. Holtedahl (24); and Th. Kjerulf and T. Dahll (27). Work has aslo been done in the area by H. Ramberg (1943, M. A. Thesis, Univ. Oslo) and A. F. Frederickson who has not yet published the results of his studies.

Petrography.

The banded gneiss commonly found in the Kongsberg-Bamble formation in Sørlandet is the rock type present on St. Hansholmen. It consists of alternating dark and light bands of quite variable thickness. On St. Hansholmen the dark bands are amphibolite, generally not less than 15 cm. nor more than 6 meters thick, and the light bands are quartz-dioritic or granodioritic gneiss and are generally somewhat thicker than the amphibolite bands. Also present are pegmatite veins and fillings between amphibolite boudins.

AMPHIBOLITE

The amphibolite is generally quite homogeneous, dark, medium to medium-fine grained and shows reticular fabric and nematoblastic texture. It consists primarily of hornblende and plagioclase. Biotite and diopside are often present in small amounts. Apatite and opaque minerals are always present as accessory minerals. In addition zircon, quartz, chlorite, calcite, sphene(?) and limonite are found as rare constituents. Hornblende needles are oriented approximately parallel to the band boundaries and dip steeply toward the west at about 60°—75°. The composition of the plagioclase is somewhat variable the range An$_{36}$ to An$_{27}$ having been observed in the thirteen thin-sections examined, the average being An$_{31}$.

The mineral composition of six sections from the amphibolite was determined. The composition of the plagioclase was determined by the maximum extinction angle together with the optical sign. The plagioclase grains are anhedral, generally slightly sericitized and smaller than the hornblende grains. Hornblende grains are generally idioblastic with ragged terminations and are quite well oriented. Hornblende shows pleochroism α = yellowish green, β = olive green, γ = deep green (the Hornblende in ØA 14 is somewhat brownish); absorption sceme $\alpha < \beta < \gamma$. Biotite generally appears as spots and small streaks in the hornblende, apparently an alteration product, except in the sections ØA 13 and ØA 15 where it exists as separate crystals and is also exceptionally abundant. The plagioclase in these two sections is less sericitized than usual. Diopside occurs in small, anhedral, pale green, non-pleochroic grains. Chlorite appears to be an alteration of hornblende when it is found. Calcite occurs in one section in a very thin vein crossing the section.

ØA 4

Plagioclase (An$_{36}$)	39.0
Hornblende	59.0
Biotite	0.5
Apatite	0.3
Opaque	1.2

ØA 7

Plagioclase (An$_{28}$)	48.0
Hornblende	45.4
Biotite	1.2
Diopside	3.5
Chlorite	0.4
Apatite	0.1
Opaque	1.5
Quartz, Calcite	< 0.1

ØA 8

Plagioclase (An$_{35}$)	41.9
Hornblende	48.0
Quartz	5.1

ØA 14

Plagioclase (An$_{28}$)	29.8
Hornblende	64.8
Diopside	4.1

ØA8 (cont.)	
Chlorite	2.5
Zircon	0.7
Sphene(?)	0.2
Opaque	1.5
Apatite, Diopside	< 0.1

ØA14 (cont.)	
Zircon	0.9
Apatite	0.2
Opaque	0.2

ØA13	
Plagioclase (An_{35})	39.6
Hornblende	52.9
Biotite	8.2
Opaque	0.1
Apatite	< 0.1

ØA15	
Plagioclase (An_{32})	44.7
Hornblende	40.7
Biotite	14.6
Diopside	0.1
Opaque	0.1
Apatite	< 0.1

Sections ØA13 and ØA15 come from an amphibolite band which contains no pegmatite veins and which seems to have been unusually plastic during the deformation of the area.

GNEISS

The gneiss from St. Hansholmen is fairly light gray to pinkish gray with a distinct macroscopic parallel structure due to the orientation and parallel structure of biotite flakes. The strike of the foliation is generally near EW and is near vertical, dipping usually to the south. On the islands adjacent to St. Hansholmen dips to the north are occasionally encountered. The foliation of the gneiss is at all times conformable with the amphibolite bands. The gneiss is mostly homogeneous, commonly medium-fine grained (most grains close to or slightly less than 1 mm.) but sometimes medium grained occasionally showing thin «schlieren» or stringers of slightly larger grain size. These «schlieren» may be quite straight but more often are slightly bent, following small flexures in the foliation of the gneiss. They are most often found at the east and extreme west ends of the island but are not restricted to these areas. They are fully conformable with the foliation in the gneiss. There is no obvious or consistant macroscopic change in the gneiss relatable to the distance from an amphibolite band.

The gneiss consists of plagioclase, quartz, and biotite, sometimes microcline, with zircon and opaque minerals always present, and epidote, apatite, limonite, sphene (?), and garnet seen in less than half of the thin-sections examined. The plagioclase lies the range An_{36} to An_{27}, average An_{31} (identical with the figures obtained for the plagioclase in the amphibolite) constituting 66.8 % to 23.8 %, average 51.1 % of the rock. It is often somewhat sericitized. Quartz always shows undulatory extinction and constitutes from 40.9 % to 25.9 %, average 35.2 % of the rock. Microcline is generally perthitic and constitutes from 35.2 % to 0.4 % average 9.6 % of the rock when it occurs, but it was not present in 10 of the 25 sections examined. Biotite is usually at least slightly altered to pennine (which is included under biotite in the percentages) and generally shows pleochroic halos. It constitutes from 8.3 % to 0.4 %, average 3.6 % of the rock. The gneiss contains maximum 98.2 %, minimum 91.3 %, average 95.4 % of feldspars plus quartz.

The mineral content of 14 sections from the gneiss was determined. In all cases the plagioclase was determined by maximum extinction angle together with optical sign. Biotite shows pleochroism γ = dark reddish brown, brown or olive brown and α = pale yellow to almost colorless yellow. Garnet occurs as rather round or otherwise anhedral grains. Quartz shows undulatory extinction. With the exception of opaque minerals which sometimes occur as medium sized grains the remaining minerals are always fine grained.

ØG 19

Plagioclase (An_{33})	57.5
Microcline	2.2
Quartz	31.6
Biotite	8.3
Zircon	0.1
Garnet	0.6
Epidote, Opaque	< 0.1

ØG 25

Plagioclase (An)	57.9
Microcline	0.4
Quartz	38.4
Biotite	2.6
Opaque	0.7
Zircon, Epidote	< 0.1

ØG 18

Plagioclase (An_{30})	36.1
Microcline	22.6
Quartz	36.2

ØG 24

Plagioclase (An_{34})	23.8
Microcline	35.2
Quartz	33.4

ØG 18 (cont.)

Biotite	4.2
Opaque	0.6
Zircon, Epidote	<0.1

ØG 17

Plagioclase (An$_{28}$)	55.4
Microcline	2.4
Quartz	39.2
Biotite	1.2
Garnet	0.6
Zircon	0.3
Opaque	0.9
Epidote	<0.1

ØG 16

Plagioclase (An$_{30}$)	53.8
Microcline	2.2
Quartz	39.2
Biotite	3.5
Zircon	0.2
Opaque	0.6
Apatite, Limonite	<0.1

ØG 26

Plagioclase (An$_{32}$)	46.1
Microcline	21.7
Quartz	30.4
Biotite	0.8
Zircon	0.1
Epidote	0.1
Opaque	1.0

ØG 20

Plagioclase (An$_{31}$)	58.4
Microcline	9.9

ØG 24 (cont.)

Biotite	6.5
Zircon	0.1
Opaque	0.6

ØG 23

Plagioclase (An$_{30}$)	52.7
Microcline	3.7
Quartz	38.1
Biotite	5.0
Zircon	0.1
Opaque	0.2
Limonite	<0.1

ØG 8

Plagioclase (An$_{30}$)	42.8
Microcline	19.0
Quartz	33.4
Biotite	4.1
Opaque	0.7
Zircon, Epidote	<0.1

ØG 12

Plagioclase (An$_{36}$)	55.5
Microcline	2.4
Quartz	38.6
Biotite	2.0
Zircon	0.1
Opaque	1.3
Epidote, Apatite	<0.1

ØG 13

Plagioclase (An$_{34}$)	49.5
Microcline	3.7
Quartz	40.9
Biotite	5.5
Opaque	0.5

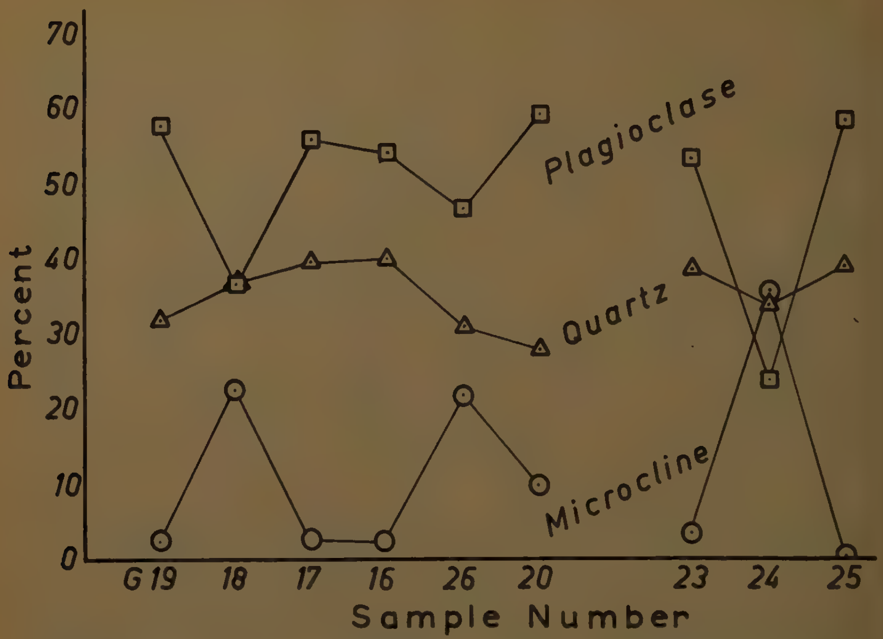

Fig. 1. The variation of the plagioclase, quartz and microcline is shown. The samples are arranged according to the position they had (see map, fig. 6) in the line across which specimens were taken.

ØG 20 (cont.)

Quartz	27.7
Biotite	2.9
Zircon	0.1
Opaque	1.0
Garnet, Epidote	<0.1

ØG 21

Plagioclase (An$_{33}$)	66.8
Microcline	4.1
Quartz	25.9
Biotite	3.1
Sphene (?)	0.1
Zircon, Epidote, Opaque	<0.1

ØG 13 (cont.)

Zircon, Epidote, Apatite, Limonite	<0.1

ØG 15

Plagioclase (An$_{30}$)	58.0
Microcline	0.4
Quartz	38.5
Biotite	0.4
Scapolite (?)	1.9
Opaque	0.7
Zircon, Epidote	<0.1

Sections ØG 19, 18, 17, 16, 26, and 20 constitute a cross-section between two amphibolite bands which passes close to the apex of a folded amphibolite band. Sections ØG 23, 24, and 25 constitute another cross-section between two adjacent amphibolite bands. The locations at which the samples were taken are shown on the accompanying map. It is to be noted that there is a distinct increase in the percentage of microcline in the gneiss away from the amphibolite bands. (Fig. 1).

PEGMATITES

There seem to be three kinds of pegmatite on St. Hansholmen. At the west end of the island there is a cross-cutting pegmatite vein varying between 1 and 3 meters in width. It is quite coarse grained, the feldspar crystals being ca. 4—5 cm. and the biotite flakes ca. 2 cm. The boundary against amphibolite is knife-sharp, but against the gneiss it is gradational over a few centimeters. This pegmatite is distinctly pink in color. It is mineralogically very simple, containning plagioclase, microcline, quartz, biotite and hornblende. Because of the grain size and the tendency to break between grains it is difficult to obtain thin-sections which can be considered representative of the rock. The plagioclase in the two sections examined was An_{35}. Microcline was not present in one section but field examination of the rock indicates that it constitutes a larger percentage of the rock than plagioclase. When seen in thin-section it showed very fine perthite (elongate blebs paralleling one twin direction) and coarse stringers of plagioclase (diagonal to the twinning directions). Quartz in both sections showed undulatory and mosaic extinction. Biotite in both sections was altered somewhat to pennine. Hornblende was not present in the thin-sections but was identified in the outcrop. The mineral composition of one of the sections of this pink pegmatite is:

ØP 17	
Plagioclase (An_{35})	34.3
Microcline (perthitic)	46.8
Quartz	17.6
Biotite	1.2

The other two types of pegmatite, hereafter referred to as «plagioclase pegmatites», are macroscopically very similar, being very light (almost white) in color and their grain size distinctly less than that of the pink pegmatite. Dark minerals are generally not abundant but may be so locally. The differences between these two types of pegmatite are their mode of occurrence and the composition of their plagioclase. One type occurs between boudins of amphibolite and the other occurs in veins (which look very much like crack fillings) in the amphibolite bands. The plagioclase of the «inter-boudin» pegmatites lies in the range An_{32} to An_{27}, average An_{29}. The plagioclase of the «vein» pegmatites is always very close to An_{20} with one exception which is An_{28}. The specimem containing An_{28} is unusual in that it is particularly rich in hornblende (18.7 %), a mineral which is uncommon in the plagioclase pegmatites. Also found by the examination of 10 thin sections were quartz (always present and showing undulatory extinction), microcline (in two sections), biotite (in 7 sections but in no case abundant), zircon (in only one section outside of its occurrence in pleochroic halos in biotite), epidote (very rare), hornblende (in three sections), apatite (rare in two sections), muscovite (as an alteration of plagioclase in one section) and opaque minerals (in four sections). For two sections the mineral composition was determined.

ØP 14	
Plagioclace (An_{20})	62.4
Microcline	6.7
Quartz	30.4
Muscovite	0.5
Zircon, Epidote	< 0.1

ØP 12	
Plagioclase (An_{20})	42.0
Hornblende	18.7
Quartz	33.2
Biotite	6.4
Opaque	0.1

The «inter-boudin» pegmatites, in four sections examined, contained quartz (always present and showing undulatory extinction), microcline (in two sections), biotite (in two sections), zircon (in three sections), and in one section each, epidote, apatite, muscovite, chlorite, hornblende, limonite, and opaque minerals. For two sections the mineral composition was determined.

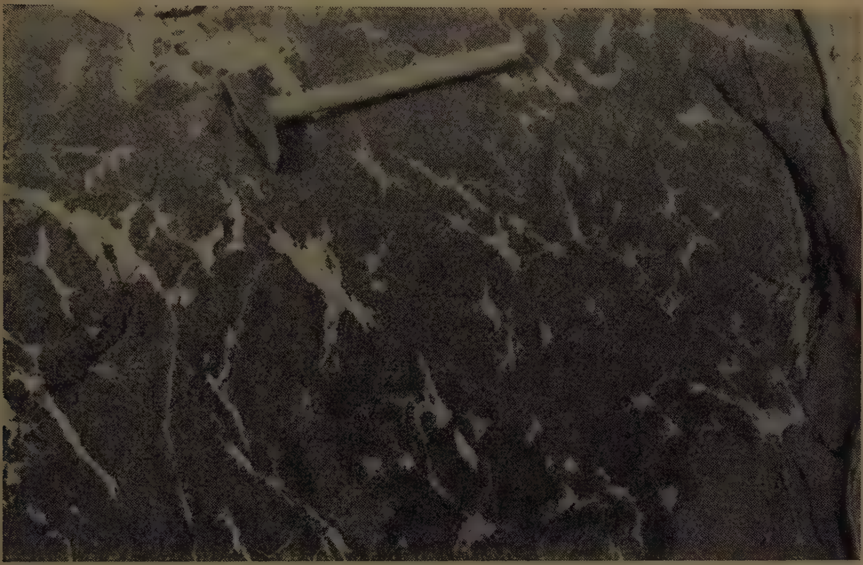

Fig. 2. The contacts between amphibolite and pegmatite are shown. At the extreme right the amphibolite-gneiss contact can be seen. There is a small concentration of dark minerals around the most centrally located of the «larger» pegmatites (directly below the hammer head).

ØP 10		*ØP 15*	
Plagioclase (An_{28})	71.3	Plagioclase (An_{27})	62.7
Microcline	1.6	Microcline	1.1
Quartz	26.9	Quartz	33.9
Muscovite	0.2	Hornblende	2.1
		Chlorite	0.2
		Zircon, Apatite	< 0.1

Sometimes there appears to be a narrow zone of concentration of dark minerals and along with this a slight increase in grain size in the amphibolite adjacent to the enclosed pegmatite veins. The concentration may be either hornblende or biotite but this bears no apparent relationship to the appearance, grain size, quartz content or dark mineral content of the pegmatite. The minerals of these concentrations are always conformable with the boundaries of the pegmatites. There are on rare occasions thin dark stringers in the pegmatite veins. These are concentrations of biotite.

The pegmatite vein — gneiss contacts and the inter-boudin pegmatite — gneiss contacts are usually very sharp but occasionally there is a zone (ca. 1—2 cm. broad) over which the line of contact is arbitrary. This occurs when the line of contact between pegmatite and gneiss is relatively long (over ca. 15 cm).

The amphibolite — gneiss contacts and the amphibolite — pegmatite contacts are always perfectly sharp, though the latter especially may be higly irregular (see e.g. fig. 2).

There is generally not a marked disconformability between the pegmatite vein boundaries and the schistosity of the amphibolite. Where there is a concentration of dark minerals at the boundary there is always conformability. Occasionally, when the pegmatite veins change direction very sharply, there is disconformability at the point of the turn.

In no case is there zoning within the pegmatites.

It is noteworthy that all the microcline containing samples of the gneiss and of the plagioclase pegmatite were collected on the eastern half of St. Hansholmen. However, though all of the gneiss samples taken from the eastern half of the island contain at least some microcline, not all of the pegmatite samples do.

Structure.

The most striking structural feature of the rocks on St. Hansholmen is a fold which can be very clearly seen on the eastern half of the island. Both limbs of the fold are revealed; the northern one more completely than the southern one. The northern limb strikes very nearly EW and the southern one about S 65—70 W. The fold axis strikes about S 75—80 W and plunges at about 60° to the SW. The axial plane is near vertical, dipping only slightly to the south. The strike of the gneiss surrounding the amphibolites parallels the bands and is at all places conformable with the amphibolite. The dip of the foliation in the gneiss and the boundaries of the amphibolite bands varies between vertical and 75° to the south.

The amphibolite bands contain many pegmatite veins and stringers which do not penetrate into the gneiss. These pegmatite veins, although often irregular and bifurcating, on the whole give the impression of being predominantly in two directions, essentially following two diagonal directions across the amphibolite bands, with one of the diagonals being dominant (i.e., for an EW amphibolite band the pegmatite veins tend to follow the directions NE SW and NW SE, with the former being dominant). This is the case on both limbs of the fold. At the apex of the fold, however, the amphibolite bands are completely broken and exist as boudins or, as is more common, there are pegmatite veins crossing the bands, these being essentially perpendicular to the band boundaries, approaching the orientation of the axial plane of the fold. (See map, fig. 6).

It appears that the sites occupied by the pegmatite veins conform to the primary zones of low pressure (fracture and/or shear) to be expected if a relatively rigid layer is folded while surrounded by relatively plastic material, the whole being subjected to confining pressure, and the fold visible on St. Hansholmen being a minor fold on the flank of a larger fold.

If the fold seen on St. Hansholmen is a synclinal fold on the southern limb of a larger syncline (or somewhat overturned anticlinal fold on the southern limb of an anticline) one should expect the development of shear primarily in the direction NE SW in *both* limbs of the minor fold. If there is simple compression normal to a layer one should expect shear planes to develop in two directions, namely NE SW and NW SE. If there is plastic flowage of the material around a given layer during compression one should expect the deformation to result either in shear planes in the directions NE SW and NW SE (or, perhaps in just one of these directions) or in simple rupture (NS) resulting in boudinage structure in the layer. A combination of the above types of deformation should then be expected to result in shear planes being developed in the directions NE SW and NW SE, with the former being the more predominant, and in boudinage structure, except at the apex of the fold where the shearing would approach the axial plane of the fold.

At a number of places boudinaging of the amphibolite bands can be seen with pegmatite developed in the area between or at the ends of the boudins. Therefore, it seems that the pegmatites in and associated with the amphibolite occupy those zones where one should expect low pressure to be developed during the deformation of the area.

At the extreme eastern end of the island it is to be noted that there is a part of a band of amphobolite which is unusually devoid of pegmatite. This amphibolite seems also to have been exceptionally plastic in its deformation. Samples from this band were especially rich in biotite. It is well established that, for example, mica schists are very plastic during deformation and it is probably due to the especially high biotite content that the deformation here was relatively plastic, thereby not giving rise to low pressure zones where pegmatites could form as easily as in most of the amphibolite.

There is a greater frequency of boudins noted in the amphibolite bands on the north limb of the fold. This may be due to the fact that the shear stress couple would be less strong here than on the south limb if this is a minor fold as suggested. The development of shear zones in the amphibolite would then be less dominant on the north limb than on the south limb and deformation by boudinaging might be expected to be more common. However, it is also possible that as the bands on the north limb are generally thinner than those on the south limb the development of boudinage structure would be facilitated and hence be more frequently seen.

The response of the surrounding gneiss at the points at which the amphibolite bands have separated suggests relatively high plasticity of the gneiss during deformation, the gneiss being completely conformable even as there occur abrupt variations in the thickness of the amphibolite. The relative thickness of the layers of the gneiss between boudins suggests that the pressure at these places was relatively low, the layers tending to be thicker between than alongside the boudins.

The fact that the pegmatite veins stop at the boundaries of the amphibolite bands and do not penetrate into the surrounding gneiss suggests that the gneiss was not sufficiently rigid to maintain low pressure zones in which the pegmatite veins could be formed.

That the fold revealed on St. Hansholmen is a minor fold on the flank of a larger fold cannot be directly established on the basis of the studies conducted by the author, but this contention is supported by the findings of a brief structural survey conducted on the islands adjacent to St. Hansholmen (see fig. 3). There is a fold present which can be traced across the southern end of Olafsholmen and to the east side of Engholmen, after which it is covered by vegetation.

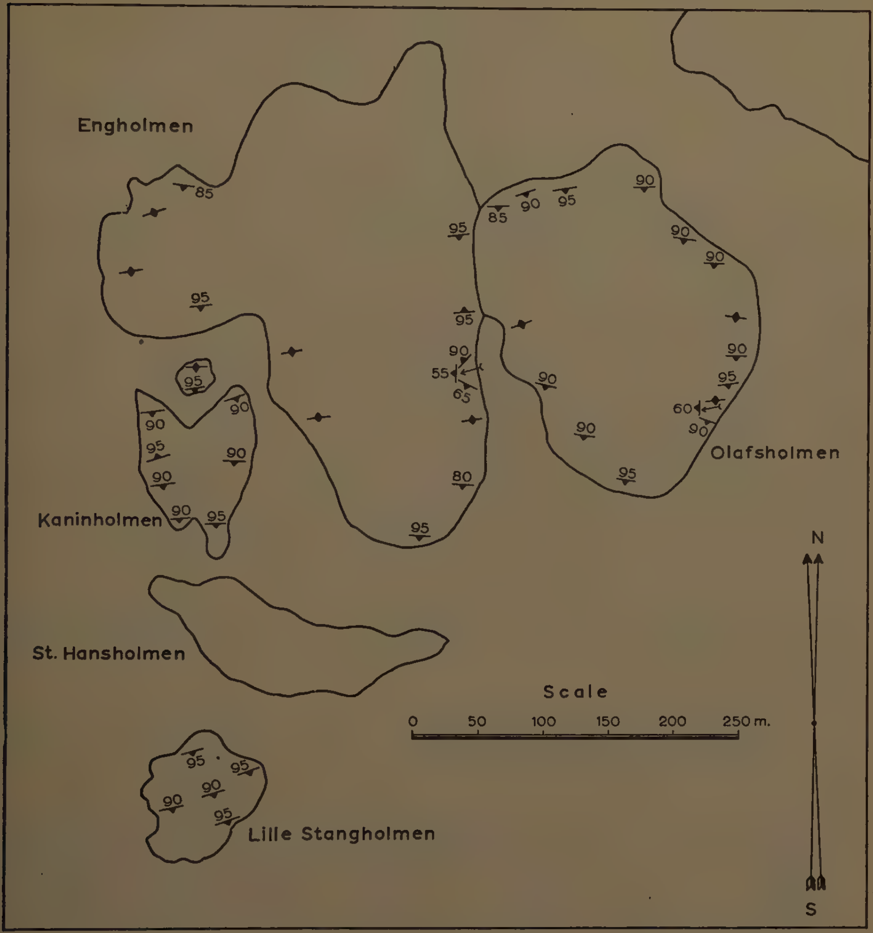

Fig. 3. The primary structure of the islands adjacent to St. Hansholmen is shown.

This fold could well be the necessary adjacent minor anticline (or overturned syncline). The axis of this fold strikes about N 85 W and plunges about 50° to 55° to the west. The axial plane is near vertical, dipping perhaps slightly to the south. The work done previously be J. A. W. Bugge (18) and by B. Hofseth (23) in the Søndeled and Kragerø areas respectively, which are the investigated areas closest to the one covered by the present study, do not cover areas which are critical to establishing the existence of the postulated structure. Neither do these investigations rule out the possibility suggested here.

Genesis.

PLAGIOCLASE PEGMATITES

The foregoing is believed to indicate quite strongly that the pegmatite veins and inter-boudin fillings on St. Hansholmen occupy areas in which there occurred fractures or zones of low pressure during the deformation of the area. Fractures or zones of low pressure are thermodynamically unstable during metamorphism and hence, when these developed, material was introduced until stable pressure relationships were re-established.

It seems that there are three possible modes of origin that can be suggested for the material now constituting the pegmatites. They are: (1) a magma introduced into the present sites where it then crystallized; (2) a hydrothermal solution which carried the material in and there deposited it; and (3) a dispersed phase of ions, molecules, or atoms which diffused toward the unstable low pressure areas and there consolidated.

On purely physical grounds the first possibility seems to be unsatisfactory. The pegmatite occurs in veins which in some cases are completely enclosed in the amphibolite and which in some cases are no wider than the width of a single crystal. In most cases, however, it cannot be shown to be comlpletely impossible that a network of cracks existed forming a narrow conduit communicating with the supposed magma. It might then be considered advisable to propose two modes of origin, but because the pegmatite veins which are without possible doubt completely enclosed by the amphibolite are mineralogically and petrographically indistinguishable from the others, one explanation for both would be more satisfactory.

The physical objection to postulating a magmatic origin for the pegmatites is that due to the viscosity of any type of silicate melt the introduction of the melt into any area through the intergranular spaces of a compact rock (i. e., through sub-microscopic channels) is impossible. The isolated location of some of the pegmatites requires that the material now constituting these pegmatites moved, at least over some distance, through the intergranular pore spaces of the

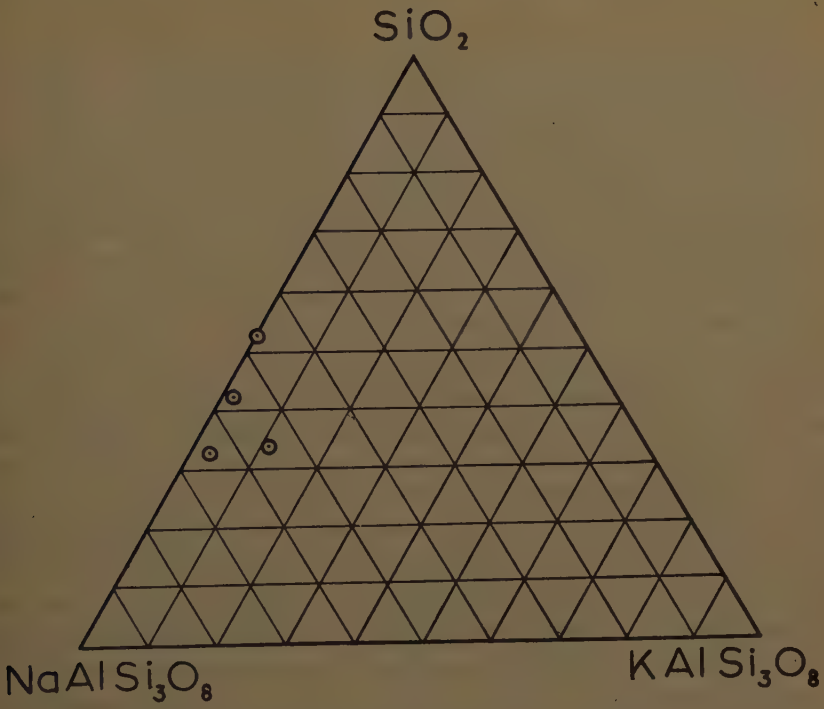

Fig. 4. Three-phase SiO_2-alkali feldspar diagram on which the composition of four of the plagioclase pegmatites is plotted.

amphibolite. The gneiss, which has been shown to have been quite plastic at the time the pegmatite material was introduced, would provide an even poorer avenue of transport for a magma than the amphibolite.

The chemical composition of the pegmatites does not in any way suggest that they were derived from a magma — especially not a magma enriched in the residual products of differentiation, such as is usually proposed for pegmatites. They are not rich in volatiles, in hydrated minerals, or in rare minerals. Also, if the compositon of the pegmatites is plotted on the three-phase SiO_2-alkali feldspar diagram (fig. 4) it is seen that the points fall well away from the low temperature trough where one should expect the composition of magmatically derived pegmatites to fall.

It seems, therefore, highly unsatisfactory to attempt to ascribe to these pegmatites a magmatic origin.

If the pegmatites are of hydrothermal origin, then just as a magma would have had to have moved through the rock intergranularly at least in part, so also would the hydrothermal solution carrying the pegmatite-forming material. Again the gneiss as an avenue of transport can be ruled out because in it the existence of openings of sufficient size and continuity to allow the passage even of a fluid having as low viscosity as has a hydrothermal solution is impossible. Hence, a hydrothermal solution would have been confined to the amphibolite, but this is quite all right as the pegmatites are also strictly confined to the amphibolite bands.

Assuming that the amphibolite was sufficiently permeable to allow the intergranular passage of the hydrothermal solution over the required distances it is neccessary that the solution would have had to have thoroughly «soaked» the amphibolite in order to have given rise to pegmatites such as those shown in fig. 2. That the amphibolite bands were «soaked» with a solution bearing the constituents of the pegmatites seems unlikely for two reasons. First, there is not found interstitial quartz in the amphibolite which should be expected to result from a solution which had penetrated into all the intergranular spaces and was in the process of precipitating the pegmatites. That is, if the hydrothermal solution had «soaked» the amphibolite there should be some traces of this in the form of interstitial quartz. Second, if the plagioclase in the pegmatites (An_{20} in the veins and An_{28} in the inter-boudin fillings) had been precipitated from a hydrothermal solution then this solution must have been in equilibrium with plagioclase of this composition. (The two types of pegmatite may have formed at different times, the composition of the solution having changed between the times, but nevertheless, the composition of the solution must have been in equilibrium with the plagioclase being precipitated at any given time.) However, if this solution had «soaked» the amphibolite it would not (at either time) have been in equilibrium with the plagioclase of the amphibolite which is An_{31}. Hence, had the amphibolite been «soaked» one should expect to find zoning or at least some sign of reaction between the solution and the rims of the plagioclase grains. This is not the case. The plagioclase grains in the amphibolite are quite uniform from the centers to the boundaries.

Friedman (20), in a study of the system H_2O—Na_2O—SiO_2—Al_2O_3, says» .... that one can have a solution at relatively low temperature (450° C) which contains components in solution that are capable of yielding rock-forming minerals. For example, a solution of [composition ca. 1.50 % Al_2O_3, 4.25 % Na_2O, 4.25 % SiO_2, and 90 % H_2O by weight %] can, if cooled from 450° to 300° C., deposit albite and quartz.» Such a solution, with some CaO in place of some of the Na_2O, moving from a warmer area (e. g., the granulite facies area to the southwest (18)) into the area of St. Hansholmen, would be just the kind of hydrothermal solution required to form the pegmatites. (Appreciably greater percentages of dissolved material seem unlikely from Friedman's diagram.) Assuming that through this temperature change 10 % of the dissolved material were precipitated in the form of plagioclase and quartz (sufficiently generous, I think, considering the ratios of the oxides in solution in relation to the ratios contained in the desired precipitate) and that the specific gravity of the precipitate is 2.6, then for every cm^3 of plagioclase and quartz precipitated from this solution through cooling it would be necessary for 244 cm^3 of solution to have passed through the amphibolite. Stated another way it can be said that for a thin sheet-like pegmatite veinlet but one centimeter thick, one meter long, and extending inwards into the rock for only one meter, 244,000 cm^3 of solution would have been necessary.

The effect that change in pressure would have on the solubility of the constituents in the hydrothermal solution is uncertain. Gibson (21) concludes «.... that only in somewhat exceptional cases is the solubility of a solid in a liquid raised by pressure ....». He lists carbonates, sulfates, sulfides, fluorides, hydroxides of some alkalis, the alkaline earths, and the heavy metals in water as exceptions. A watery solution of Al_2O_3—SiO_2—Na_2O is not included in this list.

This would suggest that one should not expect precipitation from this solution in low pressure areas. Kennedy (26) gives curves showing greater solubility of quartz in water with increase of pressure, but below ca. 700 bars these curves pass through a solubility maximum in the vicinity of 350° to 400° C. But Friedman(20), in reference to the solution of composition such that on cooling from 450° to 300° it could deposit quartz and albite, also notes that at 450° the field (from which the composition percentages given above were determined) «is occupied at intermediate pressure by albite and at low pressure by solution.» This suggests that reduction of pressure does not cause precipitation for this composition, but rather the reverse.

In the preceding discussion of a hydrothermal origin for the pegmatites it has been assumed that the amphibolite bands were readily permeable by a hydrothermal solution. It is not certain that such a solution would be sufficiently non-viscous to move through the tiny intergranular spaces of the rather dense amphibolite without having left traces of its passage, especially as such large quantities would have been required to have passed through.

The lack of volatiles or hydrated minerals in the pegmatites makes it seem somewhat unlikely that they were formed from a hydrothermal solution which, at least normally, should be expected to be greatly enriched in volatile constituents.

For the above reasons the author finds it unsatisfactory to attempt to explain the pegmatites as a precipitate from a hydrothermal solution.

That the pegmatites are the result of the migration of a dispersed phase of ions, molecules, or atoms into fractures or zones of low pressure followed by the consolidation of this phase to form the mineral grains now present seems to be the most preferable theory for the genesis of the veins and inter-boudin fillings on St. Hansholmen. On structural grounds there is no objection to this mode of origin. As has been demonstrated, the pegmatites occupy zones of shear or fracture and hence are in the places of lowest pressure during the dynamothermal metamorphism of the area. It is towards low pressure areas that diffusion of a dispersed phase is to be expected. Visible openings in the rocks surrounding the pegmatites are not required for the transport of the dispersed phase, nor is there to be expected evidence in the surrounding rocks of the passage of the diffusing material. Neither is there to be expected a reaction between the minerals of the surrounding rocks (e. g., the amphibolite bands) and the dispersed phase becaused the dispersed phase is present only because of the decomposition of the minerals in the host rock at the P,T conditions prevailing. The low pressure zone is, however, a «sink» into which the dispersed phase moves until equilibrium pressure relationships have been re-established.

The temperature of the environment during the metamorphism of the area, 460 °C, determined by the alkali content of the feldspars in

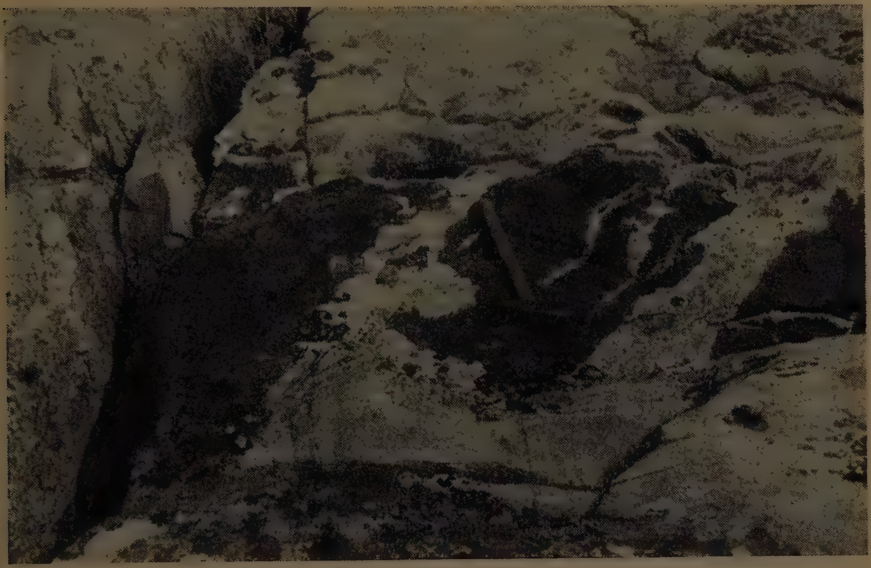

Fig. 5. Boudinage structure with the line of separation between boudins not perpendicular to the amphibolite band boundaries but following the shear direction, as revealed by the thin pegmatite veins in the boudin.

the gneiss and according to the scale given by Barth (5), is in support of this theory for the genesis of the pegmatites, being well below the temperatures of magmas. (Alkali content of feldspar determined by Miss Erna Christensen with the flame photometer.)

Provided that the assumption that diffusion may occur in rocks during metamorphism is granted, such things as the difference in the composition of the plagioclase in the pegmatites as opposed to the plagioclase in the amphibolite bands and gneiss, and the difference between the plagioclase of the two types of pegmatites can be readily explained.

As it seems quite likely that calcium is somewhat less mobile than sodium one should predict a difference in the composition of plagioclases formed by crystallization from a diffusing dispersed phase if the crystallization were at two different times. The prediction should be that earlier-formed plagioclases will be more albitic than those formed later. In the present case it seems likely that the shear zone low pressure areas caused by the bending of the amphibolite bands would have developed before the rupture of the bands to form boudins, which was caused by the compression and consequent plastic flowage of the gneiss around the amphibolite bands. The boudins shown in figure 5, where the line of separation or fracture is not perpendicular to the band boundaries but follows the predominant shear direction indicate the validity of this assumption. The fact that the vein pegmatite plagioclase is more sodic than the inter-boudin filling plagioclase (An_{20} and An_{28} respectively) corresponds with the theory of pegmatite formation through diffusion, the former having been formed before the latter, while the dispersed phase was being enriched in the less mobile constituent (calcium) through time.

That the plagioclase of the pegmatites is more sodic than that in the amphibolite and gneiss follows from the greater diffusibility of sodium as compared with calcium.

That the grain size of the pegmatites is greater than that in the amphibolite and gneiss can also be explained assuming formation from a dispersed phase.

The dispersed phase envisioned by the author exists in equilibrium with the host rocks at the prevailing P,T conditions and at low concentration. With the development of a local low pressure area a concentration gradient is created and the dispersed phase diffuses toward it. Another consequence of the development of a local low pressure zone might be the development of a nearby zone of increased pressure where the host rock minerals would, at least partly, decompose and replenish the dispersed phase. The free energy of the minerals which began to grow in the low pressure zone would be less than the free energy of the same minerals in the surrounding area. Hence there would also be a free energy gradient towards the low pressure zone. (For a more thorough account of the process of metamorphic differentiation due to heterogeneous pressure according to the diffusion theory see Ramberg, 1952, pp. 215—220). However, with a dispersed phase of rather low concentration, nucleation of minerals would not be rapid. Because a lower critical concentration is necessary for continuation of accretionary growth than for nucleation, the few nuclei formed (assuming a concentration near the critical concentration for nucleation) would continue to grow and, eventually, not being opposed by a high density of other growing grains, attain considerable size.

Sometimes zones of concentration of dark minerals around the pegmatites can be seen. These may be due to a later reaction between the pegmatites and amphibolite rather than to a selective concentration due to «leaching» of the light minerals. These zones are always very narrow (ca. 1—2 cm at most). The dark minerals are always slightly coarser grained in these zones than in the average amphibolite and are always completely conformable with the pegmatite, suggesting that the process giving rise to them involved recrystallization after the pegmatite had formed.

The numerous examples of pegmatite fillings between boudins show exactly those features which Ramberg (30), (31) has mentioned in relation to similar pegamatites studied in Greenland and elsewhere. The arguments advanced by Ramberg concerning the formation of pegmatite fillings between boudins and pegmatite veins such as occur on St. Hansholmen were convincing to the author and it is believed that the same arguments can be advanced in the present instance.

PINK PEGMATITE

On the basis of the present study nothing conclusive can be said concerning the genesis of the pink pegmatite. There have been revealed no features which are diagnostic of any one particular mode of origin. However, more detailed investigation of this pegmatite and the immediately surrounding rock is planned and it is hoped that something conclusive can be said in a later publication.

The alkali content of the perthite from sample ØP 17 was determined with the flame photometer by Miss Erna Christensen. From this determination and the optical determination of the composition of the co-existing plagioclase, the feldspar thermometer as explained by Barth (5) indicates that 610° C was the approximate temperature of formation of this pegmatite. It is perhaps noteworthy that this is very close to the temperature of 620° C. determined from a pegmatite on the nearby island of Risøen described by Andersen (1), (2). It also lies below the commonly accepted low temperature boundary for magmatic rocks.

BANDED GNEISS

The cause and origin of the banded structure in gneiss' such as those on St. Hansholmen has been much discussed, but, as far as the author knows, there has as yet been offered no unanimously accepted explanation.

The following origins for the banded structure have been suggested:

1. Differentiation processes in a solidifying magma.
2. Primary stratification of supracrustal rocks.
3. Lit-par-lit intrusion of magma along bedding planes or dominating shear planes in an older rock.
4. Metamorphic differentiation of rocks with a different structure previously.

In his work on the Kongsberg-Bamle formation J. A. W. Bugge (18) discusses in considerable detail these origins and the work done by proponents of each of them. His studies lead him to emphasize the importance of metamorphic differentiation as an agent in the formation of the banded structure, although he notes that as there exist rocks of indisputable sedimentary origin following the primary strike direction, a contribution to the banding due to primary stratification cannot be ruled out.

The present study was over a very limited area and, based on it, it is impossible to offer any new suggestion as to the origin of this structure or to criticize previous attempts to solve this problem.

Concerning the possibility that the structure is due to primary stratification of supracrustal rocks very little can be said.

There were observed no rocks on St. Hansholmen in which primary sedimentary or effusive structures were to be seen. This is not surprising as the metamorphic recrystallization is quite complete.

Based on the mineral percentages determined using the point counter the approximate weight percent chemical composition of five microcline containing samples was re-calculated. The composition taken for biotite is that suggested by T. F. W. Barth (4) for use in calculating meso- and epi-norms from the chemical analysis. It is $KA1Mg_3Si_3O_{10}(OH)_2$. This was done in order to make comparison with possible sedimentary and effusive compositions. The average of the these five recalculations is given below along with the composition of a rhyodacite (25) and one part average arkose plus one part average graywacke (28).

As can be seen the correspondence between the gneiss and either the effusive or the mixed sediment is about equally good and with

	Av. 5 gneiss'	Rhyodacite	1 pt. arkose plus 1 pt. graywacke
SiO_2	74.0	68.98	71.8
Al_2O_3	14.7	15.24	13.4
Fe_2O_3, FeO, MnO, MgO	1.5	4.39	4.9
CaO	3.0	3.01	2.0
Na_2O	3.6	3.88	2.3
K_2O	3.0	3.53	3.9

only small changes the gneiss could correspond excellently with either.

The study made of the gneiss on St. Hansholmen seems to support, at least in one respect, origin by metamorphic differentiation. The change in the microcline content of the gneiss in relation to the distance from an amphibolite band has already been pointed out (fig. 1). This change cannot be explained as due to a «leaching» process during the formation of the pegmatites in the amphibolite bands, because these pegmatites either contain no microcline or are very poor in microcline. However, it may be explained as being due to the same process as gave rise to the banded structure. The microcline was very probably among the most mobile and plastically deformable minerals present and hence was concentrated in the middle of the bands containing the relatively mobile and plastically deformable minerals. For more complete discussions of the process here mentioned the reader is referred to the works of J. A. W. Bugge (18), F. J. Turner (34), B. Sander (32), and W. Schmidt (33).

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I would also like to express my great appreciation to Prof. T. F. W. Barth for making available to me the full facilities of the Mineralogisk-Geologisk Museum and for the many helpful suggestions and enlightening discussions during the course of the study.

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BARITE WHICH DECREPITATES AT ROOM TEMPERATURES

By

Johannes A. Dons.

The determination of temperature of mineral formation by the study of liquid inclusions and decrepitation of minerals has in recent times been paid much interest. Summaries of this subject are presented by C. V. Correns in his paper «Flüssigkeitseinschlüsse mit Gasblasen als geologische Thermometer», (Correns 1953) and by Earl Ingerson in his paper «Geologic Thermometry», (ingerson 1955). It is commonly assumed that by heating the decrepitation takes place (presumably due to a sharp rise in pressure) nearly (?) at the same temperature at which the inclusions become filled with liquid (the gas bubbles disappear). In most of the cases described a real decrepitation first starts above 100° C.

A few years ago some white material with most extraordinary properties was given to the author for identification by cand. real. E. Pharo. When placed on the palm of the hand it decrepitates and tabular fragments 1—10 mm in cross section are thrown out to a distance of one meter or so. Each fragment will normally «detonate» again, when brought back to the hand. The decrepitation is accelerated when the material is slightly heated.

Refractive indices, cleavage, hardness, spectrographic determination etc. show that the white material is barite with insignificant amounts of strontium. Spec. grav. 4.33.

The mineral was found in 1949 at the farm Narum in Kolbu, Mjösen lake district, S. E. Norway. During the construction of a building a ditch, 1,5 meter deep, was cut through gravel down to the bedrock. It is uncertain whether the specimen (originally very much like the one shown in fig. 1) came from the bedrock or from the loose deposits of local origin. Much of the barite had already been

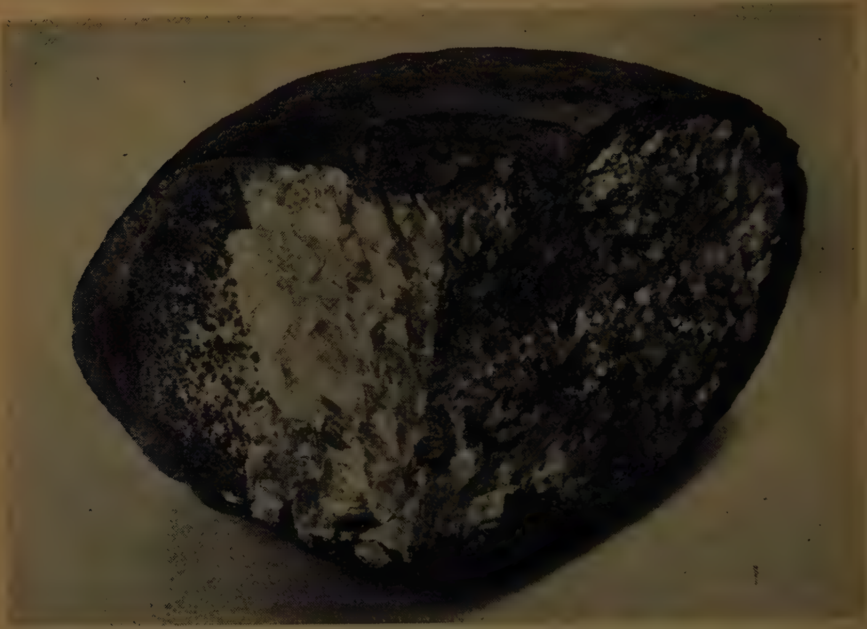

Fig. 1. 1/4 of a limestone lens, the central part of which is occupied by barite. A fossil (Lituites sp.) on the upper surface. Cephalopod Shale, probably from the Mjøsen lake district. Greatest diameter 16 cm.

spent for fun and therefore lost before Mr. Pharo got hold of it. He also tried to find more, but without success, because the house at that time was completed and everything well hidden. Small amounts of material have been used for the investigations described below and only 2—3 grams remain as reference material.

The bedrock at Narum is the black Cephalopod Shale ($4a\alpha_4$) of the Middle Ordovician Ogygiocaris Series. The shale, which is of considerable thickness, is characterized by round limestone lenses with irregular protuberances of barite on their surfaces. White or grey barite is also sometimes found in the central part of the lenses as shown in fig. 1, (also from the Cephalopod Shale of the Mjøsen lake district). From the description given by the people living at Narum the specimen fig. 1 resembles quite closely the one they found. — It is believed that the sediment was formed in a partly landlocked sea with insufficiently aerated bottom waters (HOLTEDAHL

1909, STÖRMER 1953). From the underlying Ogygiocaris Shale ($4a\alpha_3$) barite has also been described, mostly occurring as crystals on the surface of limestone lenses. As the barite seems to be limited to these and certain other shale-beds in the Cambro-Silurian sequence of Norway and Sweden it can be assumed that barium was present in the original sediment and by substitition during the consolidation of the sediment, accumulated in the limestone lenses. Holtedahl, however, maintains a secondary origin for the barite viz. that the crystals were formed by more far-travelling circulating solutions in Silurian/Devonian (pre-Caledonian folding) time.

The formation of simple crystals and concretionary nodules and lenses of barite in Swedish black shales and clayey limestone has been treated by A. Hadding (HADDING 1939), who gives the following statement: «Barytes was not formed by secondary influence. Hydrothermal, pneumatolytic and other similar processes must be entirely left out of account, as no traces whatever of such processes have been visible. The occurrence is practically simultaneous over large areas, a fact which induces us to look for regionally acting forces and conditions as barytes-forming.» .... «The material for the formation of barytes was confined to certain mud-beds, and no transport from one stratum to another can be shown.» .... «Pyroclastic material or mineral formation caused by volcanic exhalations has not been established in the barytesbearing series of strata».

The following data on barite from the Dana's System of Mineralogy Vol. II (7th ed. 1951) can be of interest for comparison with the properties of the specimen here concerned. «Barite, orthorhombic, dipyramidal» «Cleavage 001 perfect, 210 less perfect. 010 usually imperfect to indistinct but sometimes equal to 210». «Occasionally fetid when rubbed. (NH_4) has been reported in barite and liquid-filled cavities affording CO_2 or H_2S are frequently present.»

Because the material so easily breaks up on the slightest pressure or temperature-elevation ordinary thin sections could not be prepared. Naturally split thin leaves (down to 0.02 mm) have therefore been examined with and without immersion liquid and in transmitted and reflected light.

The mineral fragments are nearly always limited by the cleavage plane 001 (fig. 2), less perfect are 210 and $\bar{2}10$. No cleavage plane is developed in the 010 direction.

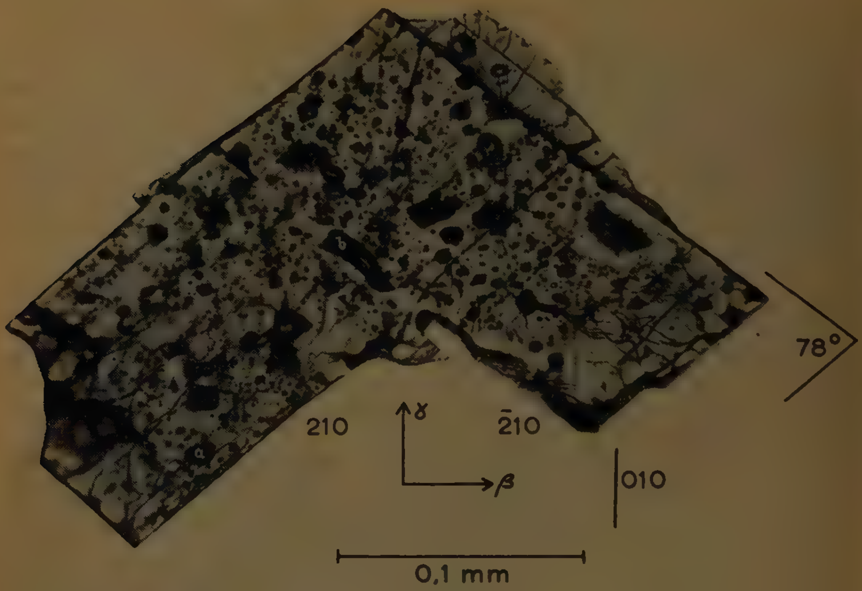

Fig. 2. Barite with inclusions, Narum. Kolbu, Mjøsen lake district. Transmitted light, no immersion liquid. Inclusions marked «a» and «b» are refound in fig. 3.

The size of the inclusions varies from 0.04 mm down to nearly nothing. They can according to their size be classified in two groups grading into each other. One group with irregularly formed and distributed inclusions 0.04—0.01 mm, and the other group with inclusions of a more regular spherical shape and of average size ∼ 0.002 mm, arranged in planes corresponding to crystallographical directions. One set of planes marked by a great abundance of small inclusions is parallel to 210 and has a spacing ∼ 0.03 mm, fig. 3. This distance and some greater ones are typical for most fragments. Another pronounced set of planes is parallel to 001. The direction 010 is not developed as a cleavage plane but can be traced as shadows probably due to a plane of inclusions, fig. 2. The inclusions are believed to be primary.

When examined in transmitted light the cavities (dark patches in fig. 2—3) appear to be single-phased containing exclusively gas or liquid. However, under reflected light some gas bubbles have been observed, which suggest that the cavities are at the stage of

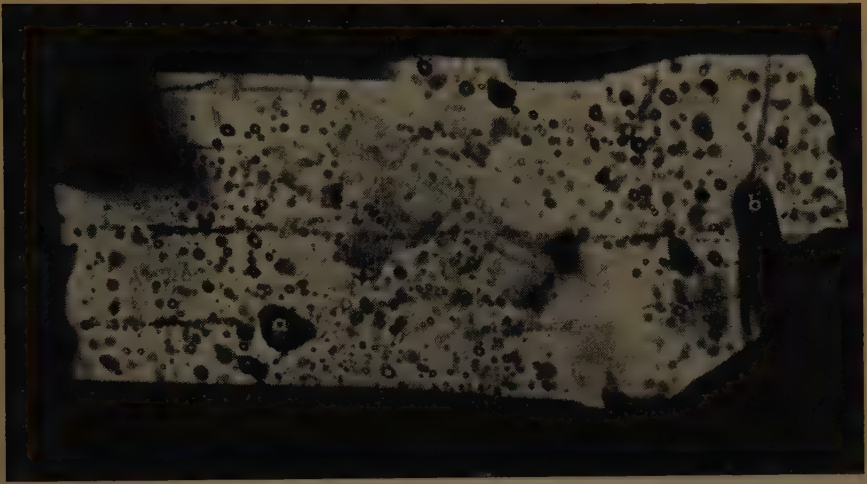

Fig. 3. The lower left part of fig. 2. Transmitted light, immersion liquid, x nic.

complete filling or very near to it. Heating stage and apparatus for the study of decrepitation have not been available, and the amount of material was insufficient for a complete chemical analysis.

When heated to 30—40° C in distilled water, the decrepitation is vigorous and at each click a gas bubble rises rapidly. The size of each bubble is approximately 10 times as great as any single cavity. When the decrepitation takes place in BaOH-solution this becomes faintly white and cloudy which indicates that CO_2 is present. A smell resembling that of H_2S is noticed when the material is rubbed or pulverised. This is not the case when the material is heated and decrepitates. Either the smell is not that of H_2S or the amount of H_2S formed by heating is too small to register. An attempt to prove the presence of H_2S by lead acetate paper was negative both when the material was rubbed and when it was heated.

A method proposed by Feigl (Feigl 1954) was tried for qualitative determination of water: «About 0.2—0.3 grams of well dried potassium thiocyanate is melted in a micro test tube. A small amout of the sample is added to the still colourless melt and the heating is continued until the melt turns blue. Filter paper moistened with lead acetate solution is held at the mouth of the test tube. In the presence of crystal water or adsorptively bound water, the paper develops a black fleck». The test was clearly positive.

It can be objected that H_2S already may be present in the material, as mentioned above. In that case, however, the content of H_2S is too small to give a black spot on the lead acetate paper, therefore it most probably must be water present in the inclusions that when heated enters into the reaction $KCNS + H_2O \rightarrow KCNO + H_2S$. The SO_4 component of barite does not disturb the reaction, and this method has been used for distinguishing gypsum from anhydrite.

In determining temperatures of mineral formation from liquid inclusions it must be assumed (INGERSON 1955) that:
1) The cavities of inclusions were filled with fluid just under the temperature and pressure prevailing during crystallization. 2) Change of volume of the mineral itself is not significant. 3) Change in volume and concentration brought about by deposition of material during cooling are such as not to affect the results. 4) Primary and secondary liquid inclusions can be distinguished under the microscope. 5) There has been no leakage from or into the inclusions. The decrepitation method has additional difficulties, one of them is that the lag between temperature of filling of inclusions and beginning of decrepitation is highly variable from one mineral to another.

Probably the decrepitation originally started at a lower temperature when the mineral first was found than it does at present. The material has been stored in rooms where the temperature has been 25—30° C. But for the following tentative considerations the temperature of decrepitation is set at 25° C. As a first approximation it is assumed that the cavities contain only pure water and that all the assumptions mentioned above are fullfilled. In that case the PT conditions prevailing at the time of mineral formation can be read from fig. 4. The line A is drawn as in the diagram published by Kennedy, (KENNEDY 1950), and concerns a mineral in which the cavities become filled at 100° C. If for instance the mineral was formed at a pressure corresponding to 2 km rock cover, the temperature of formation was 130° C. The line B for barite here considered starting at 25° C is drawn parallel to A (and due to the nearly constant compressibility of water in the interval 100—200° C, also parallel to lines within this interval, shown in Kennedy's diagram). The line C shows the geothermal gradient. In Permian time the line C has been steeper due to the large scale igneous activity. (The locality is situated less than 10 km from a great body of syenite). The point of intersection of line B and line C indicated in the diagram by «a» gives therefore the highest possible P and T conditions under which the Narum could barite be formed. Point «a» corresponds to 45° C and 1250 meters rock cover. From a geological point of view a rough estimate of the thickness of rock which at any time has covered the lens with barite is ~ 1000 meters.

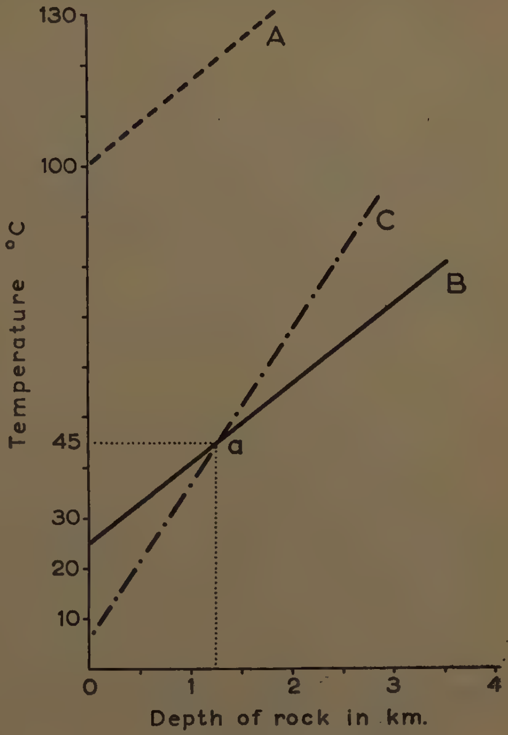

Fig. 4. Explanation in the text.

The presence of small amounts of certain gases such as CO_2 and H_2S with low critical temperatures will necessitate corrections giving a slightly higher temperature of formation (a steeper B line), whereas the presence of dissolved salts such as alkali halides will give lower temperatures.

The specimen shown in fig. 1 has a decrepitation temperature of about 80° C. This may indicate other PT conditions at the place where this barite was formed. The exact location is unknown as its lable reads: «probably Mjösen lake district, probably Cephalopod shale».

Another interpretation of this difference in temperature of decrepitation of the Narum material and the lens, fig. 1, can be the following: To make the barite crack along 001, two 001 layers must be removed a certain distance δ. In order to reach this critical value of δ the temperature of a cavity must be raised a certain amount $\triangle$ T above the filling temperature of that cavity. The bigger the cavity, the smaller is △ T. When the Narum barite therefore contains great and small cavities and the barite of the lens contains only small cavities the latter will start its decrepitation at a higher temperature than the Narum barite even if they were formed under the same conditions.

Although so much seems uncertain about the Narum barite (the exact composition of the material filling the cavities is unknown, the history of the mineral from the time it was found could not be sufficiently controlled, etc.) it seems probable that this barite was formed at very low temperature.

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COAL BLEND AND URANIFEROUS HYDROCARBON IN NORWAY

BY

JOHANNES A. DONS

The word «kullblende» (coal blend) has been used during centuries at Kongsberg Silver Works as a designation for an anthracite-like «mineral». The workers there had a rule saying that where there is no coal blend or bituminous calcite there will be no native silver. In Sweden, where similar material occurs and is beeing thoroughly studied at present, it is called «bergbek» (mountain pitch), (HELLAND 1875, HEDSTRÖM 1923). A more general designation, also used is «anthracite».

It is a jet-black, brittle, amorphous, nonfluorescent mineral, see figures 3, 5, 6, 7. Spec.gr.: ~ 1.3, hardness: 2—3 (fracture surfaces give the idea of ~ 5), streak: black, fracture: conchoidal, lustre: vitreous. Composition in weight per cent: carbon 95—80, oxygen 6—2, hydrogen 3—1, nitrogen 0.7—0.2, sulphur 0.4, ashes 4—0.1. Chemically the specimens from some localities differ greatly from these figures. X-ray examination carried out on material from most of the 20 localities usually showed more or less pronounced graphite lines.

All known occurrences of coal blend in Norway are listed below, starting in the southern part of the map area fig. 1. Some of them have been mentioned and described in earlier literature, others are only known because collected material has been stored in this museum. A couple of new occurrences have been discovered by the author who also wishes to thank his colleagues for furnishing him with further information.

As shown by the map, all localities of coal blend are to be found in Southeastern Norway, near and inside the Oslo Region (graben area) in Precambrian, Cambro-Silurian and Permian rocks.

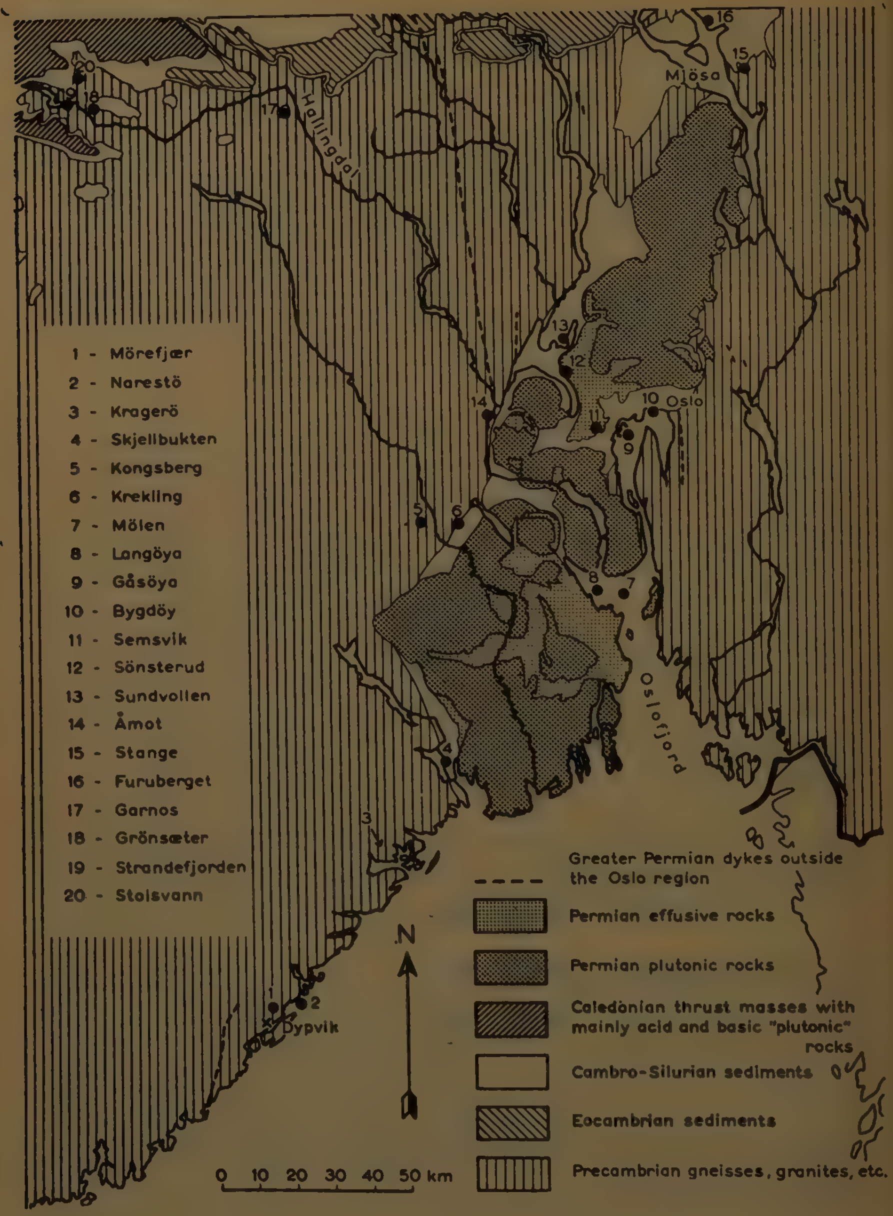

Fig. 1. Map showing the location of 20 occurrences of coal blend.

Loc. 1. Mörefjær, Arendal. Precambrian area.

In the skarn iron ore mines, the Mörefjær mine especially mentioned, (BUGGE 1954), small grains of coal blend have been observed in a mass of chlorite. It is considered to be a young mineral which occurs together with analcime, prehnite, heulandite, calcite and other hydrothermal minerals. The age of the hydrothermal activity is unknown.

Loc. 2. Narestö, Arendal. Precambrian area.

Specimens of coal blend from Narestö feldspar quarry (opened in 1792 on a granite pegmatite) were presented to this museum in 1909 by Christiania Minekompanie, and in 1936 by Mr. Suleng. The total amount of material at disposal was approximately 25 grams.[1] In the description of the quarry (ANDERSEN 1931) the following minerals are mentioned: alkali feldspars, quartz, biotite, plagioclase, magnetite. Also radioactive minerals such as orthite, monazite and xenotime are reported, but no coal blend. The museum specimens seem to indicate that the rock in which the coal blend occurs has been altered by hydrothermal solutions.

Beta (and gamma) - ray counts carried out in the Norwegian Geological Survey Laboratory on the whole material of coal blends from Southern Norway gave a radioavticity of $\sim$ 2 per cent equivalent U_3O_8 for the Narestö specimens and nothing for all the others.

An analysis, partly chemical, partly spectrographical, performed at the Institute for Atomic Energy gave the following result in weight per cent: 95 «organic» material, 1.8 U_3O_8 no ThO_2, appreciable amounts of B, Si, Mg; traces of Mn, Fe and Ca. No V_2O_5 is here reported but its presence has earlier been proven by Dr. H. BJÖRLYKKE.

This means that the coal blend of Narestö has an ash content of 5 per cent and that the U_3O_8 content of the ash is 36 per cent. As Th is lacking the designation thucholite is incorrect for this material. The name «ucholite» would be better. Also in the uraniferous hydrocarbon from Laxey, Isle of Man, thorium is not present in detectable quantity. (DAVIDSON and BOWIE 1951).

As seen in the table of analyses (fig. 2, first and second column) the Narestö coal blend also differs greatly from the others by its

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[1] The author, visiting the quarry in July 1956, was unable to find any coal blend.

Fig. 2. Analyses of coal blend and other carbonaceous material.

	Loc. 2		Loc. 5			Loc. 11	Loc. 12	L. 14	L. 18				
Weight %	Narestö Arendal Helland 1875	Narestö Arendal New anal.	Kongsberg Helland 1875	Kongsberg Neumann 1944	Kongsberg New anal.	Semsvik Bugge & Neumann 1939	Sönsterud Kristoffersen 1939	Åmot Modum New anal.	Grönsæter Hol New anal.	Carbonites Brittle, non fusible Mueller 1954	Antracite coal Av. of 16 anal. Clarke 1920	Average of 4 Antraxolites. Dunn & Fischer 1954	Average of 4 Schungites. Inostrazef 1880
C	69.1	74.1	95.4	90.5	93.4	86.5	86.3	93.6	79.2			91.52	98.11
H	2.9	3.1	1.9	2.2	1.6	2.9	3.37	0.9	0.7			3.15	0.43
N	tr		tr	0.5		0.7	0.19					1.05	0.43
S	0.2			0.4		0.5	0.38					0.52	
indir. O	15.6		2.2	5.5		5.7	2.29					2.68	
H_2O-							1.17						
$CaCO_3$							6.3						
Ashes	12.2	5.0	0.4	0.9	1.8	3.7		0.1	16.2	0.51		1.08	1.09
Weight % without ashes:													
C	78.8	78.0	95.8	91.3	95.1	89.9	93.2	93.7	94.5	84.7	93.5	92.52	99.2
H	3.3	3.3	1.9	2.2	1.6	3.0	3.7	0.9	0.8	6.1	2.8	3.18	0.4
N	tr		tr	0.5		0.7	0.2			0.9	1.0	1.06	0.4
S	0.2			0.4		0.5	0.4			1.3		0.53	
O	17.7		2.3	5.6		5.9	2.5			7.0	2.7	2.71	
	100.0		100.0	100.0		100.0	100.0			100.0	100.0	100.0	100.0
Atom.prop.													
H/C	0.52	0.50	0.24	0.29	0.20	0.40	0.46	0.12	0.10	0.40—1.15	0.36	0.41	0.05
O/C	0.17		0.02	0.05		0.05	0.02			0.02—0.07	0.02	0.02	
Spec. grav.	1.64		1.38	1.49		1.3—1.4	1.2—1.37	—	1.8	1.21—1.25	1.65	1.38	1.84

low content of carbon and high content of oxygen and ashes. Microscopic investigations of a polished section reveals subangular mineral grains, probably uraninites (light grey to yellowwhite in plane-polarized reflected illumination) which make up about 5 per cent of the material which for the rest consists of normal coal blend (grey with no reflection pleochroism or effect of anisotropy) and pyrite.

It can probably be assumed that the coal blend mentioned in old literature from «granitiske Udskeidninger» (rocks derived from granite) by Arendal refer to the Narestö quarry. (WEIBY 1849).

*

In this connection may be mentioned the so-called oil diabases (doleritic dykes) from the Arendal area which have been known to geologists for a century, but not mentioned in the literature. One of the dykes a couple of meters wide and nearly vertical is seen in the good road section on the NW side of the little bay Dypviken, 3 km NE of Arendal. When splitting up the rock so that the amygdales (up to 1 cm in cross section, coated with quartz and calcite) are disturbed wet patches grow out from the hollows. The liquid has the typical smell of petroleum, and some times one can succeed in getting it burning before it evaporates completely. It is reported that someone had the liquid analysed and it showed a close resemblance to Caucasian petroleum. The dyke rock shows no radioactivity.

Several diabase dykes have been mapped by Dr. J. A. W. BUGGE during his study of the Arendal area, a few of them being of the Dypviken oil-bearing type (oral communication). The diabase dykes are the youngest rocks in this Precambrian area. They may be of Permian age.

Loc. 3. Kragerö. Precambrian area.[1]

Coal blend has been reported from the Kragerö district (DAHLL 1861) and is said to occur in dykes and to be related to intrusions of gabbro. The exact location of this occurrence is unknown and no specimens exist any longer.

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[1] In a new road section at Hullvann 7 km N of the town Kragery (Loc. 3 in fig. 1) cand. real. S. Skjeseth this summer found coal blend in a N-S-running breccia 2—3 m thick. This breccia forms a part of a greater and older breccia. The coal blend, mainly leafshaped, is found between the crystals of calcite and and quartz which fill the spaces between the partly round, partly sharpedged pre-Cambrian gneiss fragments. The coal blend is non-radioactive. The younger breccia may be of Permian age.

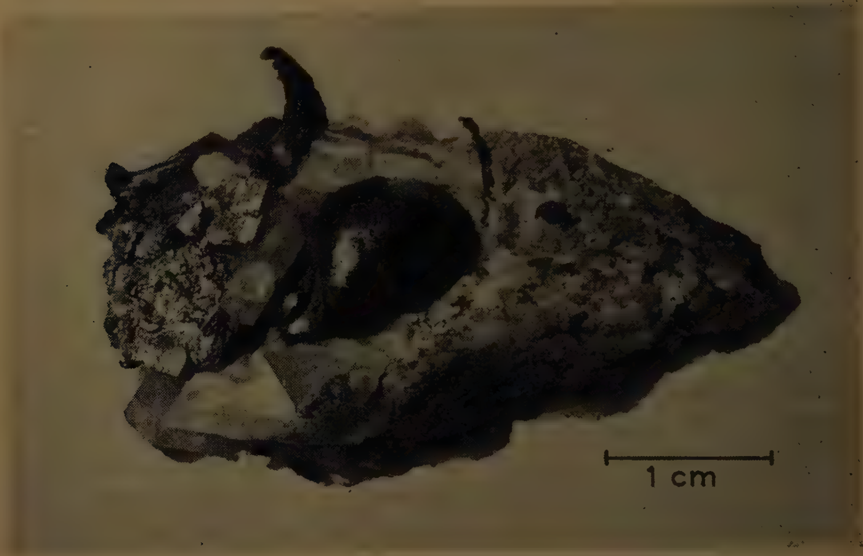

Fig. 3. Globule of coal blend in calcite. Threads of native silver. on the upper surface of the specimen, pyrite to the left. Kongsberg, loc. 5.

Loc. 4. Skjellbukten. Ordovician sedimentary area.

During a student excursion in 1949 the author found some handfuls of coal blend occurring together with calcite in a minor brecciated zone cutting vertically the Encrinite limestone (Ordovician). The material was taken to Finland for analysis.

Loc. 5. Kongsberg. Precambrian area.

The coal blend is tolerably common in the hydrothermal veins worked in the Kongsberg silver mines, (Helland 1875, Vogt 1899, Leitz 1939, Neumann 1942). Dr. H. Neumann reports that botryoidal, spherical or globular forms are here the usual way of occurrence, their size being from almost nothing to more than that of a hen's egg (fig. 3). The minerals is found in vugs fixed to other minerals, as well as along cleavage planes of calcite, and even on the tip of «threads» of native Ag. Coal blend of irregular shape, and coal blend as fan-shaped leaves coating silver minerals has also been observed.

According to Dr. Neumann the hydrothermal vein minerals occur in three paragenesis, rather intimately connected with each other:

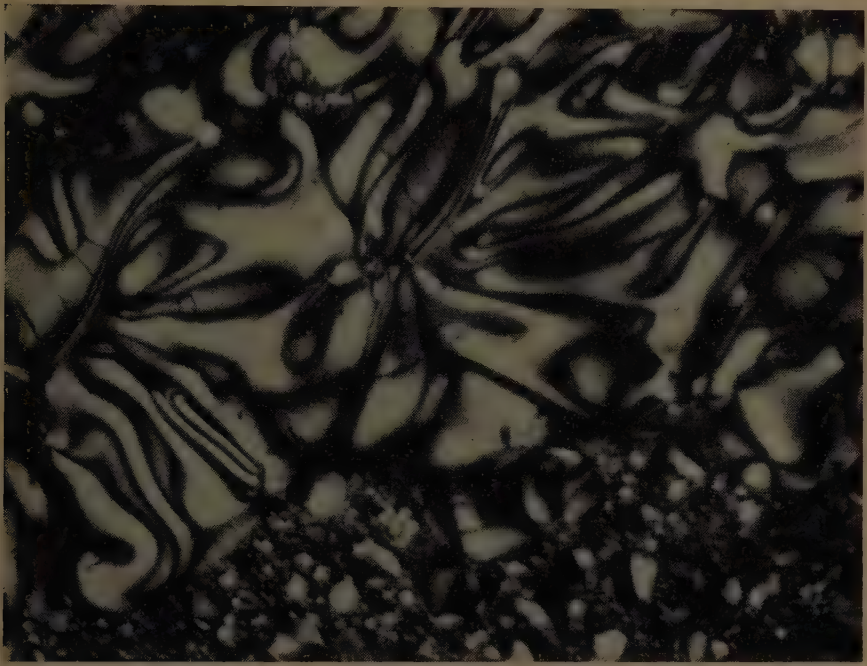

Fig. 4. Photomicrograph of the Kongsberg coal blend. Polished section, crossed polars. Side length of picture corresponds to 0,5 mm.

the older quartz- coal blend-fluorite- axinite-pyrite paragenesis, a middle calcite-barite-fluorite-sulphide-silver-Ni- Co-arsenide paragenesis, and a younger calcite-zeolite paragenesis. The age of the coal blend and its place in the paragenesis is difficult to decide because of the absence of crystallization. It seems to have been precipitated at various times. It is, however, usually very young.

All the veins are narrow and they cut east-west across a Precambrian series of rocks, mainly banded dioritic and granitic gneisses. A swarm of Permian diabases which crosses the area is closely connected with the older quartz veins as well as the calcite-native silver veins, and has the same direction. The veins are most probably connected with the younger igneous activity of the Permian Oslo Region. The pressure under which the minerals have been deposited must, according to Neumann, have been about 1000 atm. and the temperature has probably varied from about 400—500° C to about 200° C.

Both J. Leitz and H. Neumann observed that the coal blend, in polished section, showed a very great reflection pleochroism, a definite effect of anisotropy and a low reflective capacity. Coal blends from other localities in SE Norway show none of the above mentioned optical properties. Leitz has observed an intergrowth of parallel stripes, where the individuals of the anisotropic minerals are oriented approximately vertically to each other. Neumann states that the polished specimens of coal blend he has seen were built up from almost parallel, probably leaf-shaped individuals. Leitz stresses the similarity with graphite (Retort graphite). Neumann's Debye-Scherrer diagram of coal blend gave a few indistinct lines which did not coincide which any of those of graphite.

X-ray diagrams taken up for this investigation gave the lines for graphite, sphalerite and calcite.

A new polished section prepared from a globule of Kongsberg coal blend showed the optical properties mentioned above, but quite another pattern (fig. 4). However, this also resembles some of the types of «Retort graphite» (RAMDOHR 1928).

The chemical analyses are given in fig. 2. An x-ray spectrogram of the ashes from the Neumann analysis showed vanadium.[1]

As mentioned above the coal blend is found in the mines at Kongsberg even at great depth (~1000 meters below the surface). This will correspond to ~1500 m below the now denuded Cambrian alum-shale and ~2000 m below the Permian sediments. Coal blend has also been found outside the mine area, for example at Basserudåsen S. E. of Kongsberg, and at the small Tjennerud lake E of Kongsberg.

Loc. 6. Krekling, Eiker. Cambrian area.

In the core from a drillhole through alum-shale at Tangen a few, small grains of coal blend have been observed. Together with calcite and pyrite they form a thin vein cutting a nodule of black limestone. The exact stratigraphical situation is Parabolina heres-beds, 2 dε.

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[1] The C_{12}/C_{13} ratio has been determined on Kongsberg material by Professor Wickman (Stockholm) with the following result: Calcite 89.69 89.58 89.24 88.73. Coal blend 91.16 91.12. No definite conclusion as to the origin of coal blend can be drawn from these results.

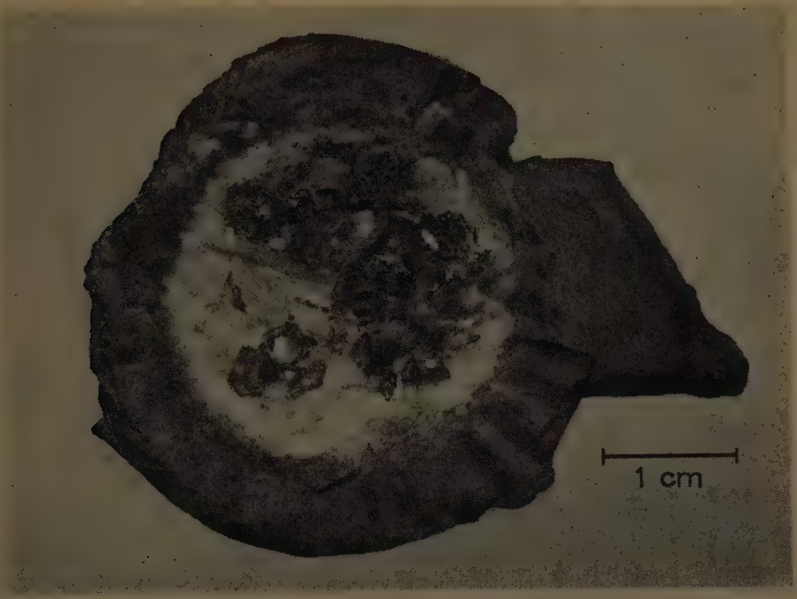

Fig. 5. Coal blend in calcite forming the central part of Echinosphaerites sp. Gåsøya, loc. 9.

Loc. 7. Mölen, Oslofjord. Precambrian area.

During an excursion in 1943 coal blend was found in thin calcite-fluorite-pyrite fissures which cut an amphibolite on the SE-side of the island. The coal blend is leafshaped.

Loc. 8. Langöya, Holmestrand. Silurian area.

The upper Silurian limestone (stage 9) building up the Langöya island is extensively quarried for use in the Portland Cement Factory at Slemmestad. The workers could at the author's request, confirm that coal blend which he found in a calcite vein, is quite frequently seen in the numerous crosscutting veins.

Loc. 9. Gåsöya, Oslofjord. Ordovician area.

A specimen of Echinosphaerites sp. was collected from the SW part of this island in shale between limestone beds (stage 4aβ — 4bα) by Dr. Örvig in 1941. The central part of the fossil is made up of calcite with some irregular grains of coal blend. Fig. 5.

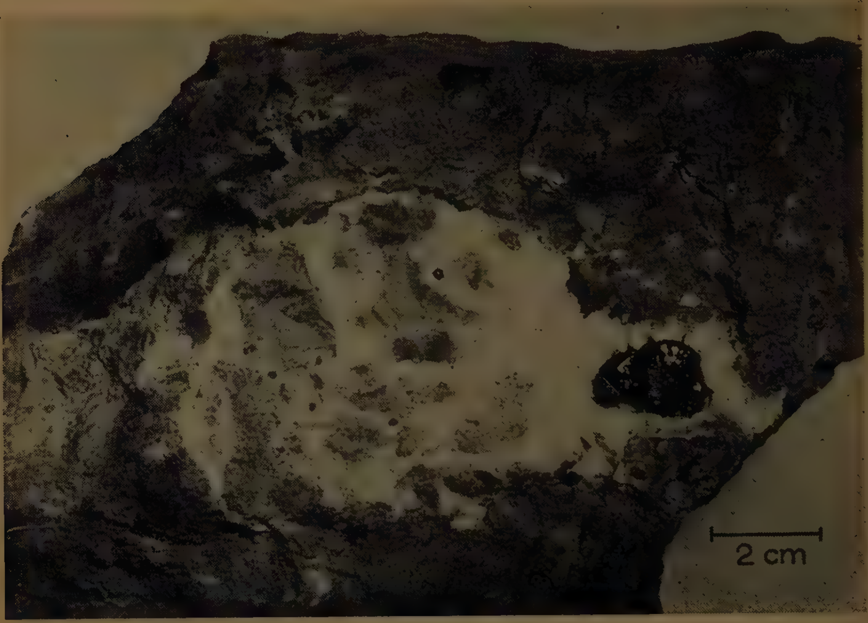

Fig. 6. Nodules of coal blend in calcite, Rhomb porphyry. Sønsterud, loc. 12.

Loc. 10. Bygdöy, Oslofjord. Ordovician area.

In the teaching collections of the University coal blend is represented by a specimen from Bygdöy sjöbad. Here it occurs together with calcite and pyrite as fine grains in a thin vein cutting black shale of lower Ordovician age.

*

During his field studies of the Cambro-Silurian in Oslo and surroundings cand.real N. Spjeldnæs has often observed coal blend, in vertical calcite veins, especially where these cut across Cambrian and lower Ordovician sediments.

Loc. 11. Semsvik; Asker. Permian lava area.

The lower basalt, B_1, (the essexite lava E_1 of Brögger) overlaying the Permian fossiliferous beds at Semsvik contains cavities coated with small globules of coal blend as well as quartz, epidote, calcite and prehnite. (BUGGGE, NEUMANN 1939). Specimens have not been available to the author. The chemical analysis is tabled in fig. 2.

Loc. 12. Sönsterud, Tyrifjord. Permian lava and sandstone area.

Coal blend was discovered in 1938 in cavities and fissures of the lower rhomb porphyry lava RP_1 exposed in a road section near Sönsterud (KRISTOFFERSEN 1939). The mineral has the form of nodules (fig. 6) or fingershaped individuals and is always followed by calcite and locally also by fluorite. Chemical analyses are tabled in fig. 2. Spectrograms taken of the ashes show vanadium as a main component.

During detailed field investigations in this area the author happened to find small grains of coal blend also in the beds below the rhomb porphyry, viz. in a $^1/_2$—1 meter thick bed of sandstone and the underlaying basalt B_1 (DONS 1956).

Loc. 13. Sundvollen, Tyrifjorden. Silurian area.

It is related that coal blend has been found in road sections along the lake Tyrifjord between Sundvollen and Vik. Details are lacking, but it is assumed that the mineral occurs in narrow calcite veins intersecting upper Silurian shallow water sediments, stage 9.

Loc. 14. Åmot, Modum. Precambrian area.

A carbonaceous substance found by the workers in the quarry «Åmot pukkverk» was in the spring 1955 sent by the director of Åmot agricultural school, Mr. Heldal to this museum for identification. It proved to be coal blend. The quarry, which is worked for road material, was visited by the author May 1955. It is situated on the western side of the river Dramselven between the Åmot bridge and Embretsfoss factories at a distance of $1^1/_2$ km from the Cambrian alum-shales of the Oslo region. The steep hillside is built up of brecciated rocks forming a zone striking *N-S* in Precambrian amphibolite

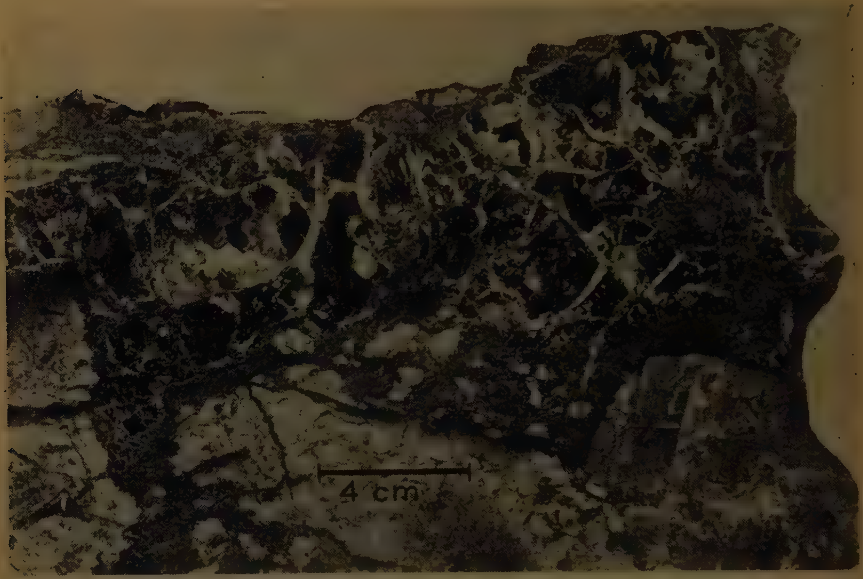

Fig. 7. Coal blend from Åmot, loc. 14. One great crystal of calcite is seen in the lower right part of the photo.

gneisses and quartz-mica-schists rich in actinolite. The breccia zone is believed by the author to be of Permian age, and may be regarded as a part of a faultsystem in the Precambrain area forming the western side of the graben of the Oslo Region. The base level of the quarry is situated 2—400 meters below the formerly existing sub-Cambrian peneplan and the Cambrian alum-shale.

The coal blend (fig. 7) is found in great amounts at one place in the breccia zone in the quarry. One gets the impression that the coal blend originally formed more or less horizontal layers, strings or clusters, 5—10 cm thick which later, due to shrinkage during consolidation, broke up in all directions, the interspaces being filled in with calcite etc. Great crystals of calcite 10—30cm across are often found close to the coal blend. Slickensides on planes of various directions are frequent within the breccia zone. One system of planes is nearly horizontal.

The quarry workings include two parallel Permian diabase dykes. They strike north-south, like the breccia zone in which they are found. The lack of coal blend in calcite fissures of the diabase dykes cannot be used for dating the formation of coal blend, because the occurrence of this mineral is limited to another part of the quarry. Thin sections show that there seem to be two generations of coal blend formation separated by an interval of slight movements, because dark parts of the rock, pigmented by rubbed coal blend, are cut by thin veins of undisturbed coal blend. The lighter parts of the breccia are composed of oligoclase formed secondarily, but prior to the coal blend.

The undisturbed greater masses of coal blend which suffered a shrinkage during consolidation became interwoven by hydrothermal veins composed of calcite, quartz (with undulating extinction!) chalcopyrite and chlorite. The latter mineral is pale-green in colour composed of fans and has an average refractive index of 1.61, weak birefringence and abnormal blue to violet interference colours. The birefringence and the interference colours are characteristic for penninite but that mineral has a lower index. The x-ray diagram also resembles that of penninite but is not absolutely identical. The chlorite is, as mentioned before, found in the coal blend, but it also occurs in the berccia rock in contact with the coal blend where it can be seen with a hand lens as laths or rectangular tablets.

The ore microscope reveals no inhomogenety in the coal blend like that observed in the Kongsberg material. The Åmot mineral shows thus no reflection pleochroism and no anisotropy. It has light grey smooth surfaces.

The chemical analysis performed on material previously treated with HCl-solution shows that the content of ash is very low, the results being 0.0 and 0.1 per cent.

A spectrographical analysis performed on material heated to 500° C gave the following content: Ca, Mg, Fe, Al, V ($^1/_2$—1 per cent) Ni, Mn, Mo and traces of Ag, Cu, Ti, Yt, Pb, Co. Another analysis of coal blend on unheated material gave: V, Ca, Fe, Si, Mg. The analyses show that vanadium is a typical element in the coal blend as was also the case with the Kongsberg and Sönsterud material. Many of the other elements, such as Ca, Mg, Fe, Si, Al etc., are derived from minerals found in microscopic veins in the coal blend. It is remarkable that no uranium lines could be identified, because one type of uranium bearing mineral (and ilmenite) was found at several places near the accumulations of coal blend.

Loc. 15. Stange. Precambrian area.

The second railway section south of Stange near the lake Mjösa crosses a Precambrian mylonite zone in which coal blend has been found, together with calcite and ankerite in thin fissures and veins (KJERULF 1885). No material is now available.[1]

Loc. 16. Furuberget. Ordovician area.

In the middle Ordovician «Mjösa Limestone» (zone 4bδ) 80 m thick, cand.real S. Skjeseth has observed local occurrences of coal blend in calcite veins. No mateiral is available at present.

Loc. 17. Garnos, Hallingdal. Volcanic breccia in Precambrian area.

The Permian (?) Garnos breccia which is composed of fragments of Precambrian rocks and Cambro-Silurian sediments has a groundmass pigmented and impregnated with carbonaceous particles (BROCH 1945). The microphotographs and the description show that the carbonaceous material is also found in narrow veins and scattered amongst the mineral-fragments of the groundmass. Pieces up to the size of a nut have been found. Broch concludes: «The coal may originate from volcanic gases — in that case being the only trace of them — or may be a distillation product of bitumen from Cambrian shales fallen to greater depths through the chimney». No detailed analysis of the material has been performed, but it is believed that the carbonaceous material has a composition which corresponds to the coal blend.

Loc. 18. Grönsæter, Hol, Hallingdal. Precambrian area.

«Coal» from this locality was in 1915 brought to the Geological Survey and the director visited the area the same year. (REUSCH 1920). In his publication (with English summary) he uses the expression carbonaceous substance, but the appearance and properties make it clear that it is coal blend. The mineral occurs scattered over a distance of 1 km in a 100—200 m thick bed of quartzite belonging to the Precambrian Telemark-formation. The coal blend is cut by veins of quartz, but no calcite can be seen. There is no sharp junction between quartzite and layers or patches of coal blend. Pieces as large as an apple have been observed in layers $^1/_2$ m long and 20 cm thick. Fig. 2 gives the chemical analysis characterized by a high content of ashes. The specific gravity is consequently high and variable, the average being 1.768 (4° C) and max. 1.950. Coal blend in our museum from this locality as from all the others will not burn, but people living at Grönsæter have said that some of this material really burned.

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[1] In Solör near the main road passing Rönåsmyren between Hukusjöen and Glomma (just outside the map area, fig. 1, 50 km SW of loc. 15) cand. real. S. Skjeseth this summer found coal blend in a NNW-running breccia in NNW-striking mylonitized pre-Cambrian gneiss. The breccia fragments are coated with small quartz crystals. Coal blend is found in the partly open space between the coated fragments. The coal blend is non-radioactive. The breccia most probably indicates a southern continuation of the important Permian Rendalen-fault, which in that case can be traced for a distance of 200 km. Also cand. mag. A. Hjelle found coal blend in pre-Cambrian rocks this summer. It occurs near the farm Östby 9 km S of loc. 15 in a N—S-running breccia zone.

Loc. 19. Strandefjorden, Hol. Precambrian area.

This and the following occurrence of coal blend have been found by director Dr. C. Bugge while acting as geological adviser to Oslo Lysverker during the construction of water barrages and tunnels in this district for water-power. Dr. Bugge has kindly informed me that small grains of coal blend were found in a mica sandstone near the border of granite at the eastern end of Strandefjorden. These rocks belong to the Telemark-formation. The sandstone is porous and beautifully brecciated.

Loc. 20. Stolsvann, Hol. Precambrian area.

The coal blend was also here found at the place where the barrage was to be constructed. It occurs in cavities in the so-called «Dagali gneiss» near bedded sandstone.

*

Hypothesis of origin and conclusions.

Coal blend is a complex of carbon-hydrogen-oxygen-compounds with traces of nitrogen and sulphur. The content of graphite, as well as other components, varies in the same occurrence and from one occurrence to another.

For considerations concerning the mode of formation it is to be noted: 1) that the Cambrian alum shale, which once covered the whole area where the coal blend is found, contains small quantities of carbon and vanadium; 2) that the Cambro-Silurian sequence is composed of fossiliferous limestones and shales and that parts of this sequence also covered the same area; 3) that the Permian sediments of insignificant thickness formimg the base of the lava series contain fossil plants; 4) that the Carboniferous epoch is not represented by any rocks in Southern Norway, and finally 5) that the Permian igneous activity can be traced by means of dykes etc. far outside the graben area itself, (see fig. 1 where also some of the most prominent dykes are indicated).

The Narestö coal blend looks like the material from the other 19 localities but differs by containing a uranium mineral. It is also the only occurrence of coal blend in pegmatite. The properties and mode of occurrence harmonize fairly well with that of the thucholites, Th is however lacking. Examples of such radioactive hydro-carbon aggregates are recorded in a most interesting paper by DAVIDSON and BOWIE, 1951, where also previous literature is summarized. It is believed that radiations from preexisting radioactive minerals have polymerized hydrocarbon compounds present in hydrothermal solutions, thus stopping further circulation of these compounds by a condensation around the nuclei of minerals. The chemical analysis of the Narestö material calculated as ash-free material shows a higher content of oxygen and a lower content of carbon compared with the other coal blends. This may be due to the bombardment of alpha and beta particles sent out by the radioactive mineral, a treatment which did not take place in the other cases. (Non-radioactive carbon material is described by DUNN and FISCHER 1954, and by MUELLER 1954).

All the occurrences of coal blend can be of hydrothermal origin. Concerning the Narestö (and Mørefjær?) material the hydrothermal activity may be of Precambrian or Permian age, for all the others a Permian age is supposed.

It is believed that the original hydrocarbon fluids had a reasonably constant composition and that the different properties now observed in the coal blends are due to the mode of polymerisation under varying conditions.

Most of the coal blends, if not all of them, have in all probability passed through the state of gels which became concentrated in zones of comparatively high porosity. Subsequent changes of the protocoal blend to a viscous mass led in some place to the globular structure, and elsewhere to more or less regular layers which suffered a decrease in volume when the viscosity gradually increased, producing a brecciated structure. The filling of fractures by hydrothermal minerals (calcite, quartz, chlorite, etc.) indicates that the whole process of solidification took place in the hydrothermal stage.

The hydrocarbon content of the hydrothermal solutions may have been juvenile in the Permian magmas, most probably in the granitic ones. The parent material may also be Cambro-Silurian sediments assimilated by these magnas. That the magmas may contain carbon-hydrogen-oxygen compounds is made probable by the occurrence of «petroleum» in the diabases in the Arendal area (described above under loc. 2).

It can be objected that the loc. 18, 19 and 20 are found at too great a distance from the Oslo region to have been influenced by hydrothermal solutions from Permian magmas. However, it must be remembered that breccia-zones of Permian age or reworked in Permian time, during the later years of study have been traced very far outside the Oslo region. (Broch 1950).

A few other hypotheses of origin mentioned briefly below may of course be considered, however, they all seem to be less probable. The coal blend could originate directly in the Cambrian (carbon bearing) alum-shales or other fossiliferous Cambro-Silurian (and Permian) shales. If there is only one source of material, which is believed to be the case, the hydrocarbon must have passed downwards at least to the deepest levels in the Kongsberg mine as well as upwards through the Permian lavas. A local reduction of limestone giving a hydro-carbon compound of the coal blend type seems improbable as the presence of such unknown reducing agents would have influenced the rest of the rock in a noticeable way.

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Universitetets Mineralogisk Geologiske Museum, Oslo, mars 1956.

Manuscript received, April 7, 1956.
Printed, December 1956.

GEOLOGNYTT

Fellesstyret for Norges Geologiske Undersøkelse, Geofysisk Malmleting og Statens Råstofflaboratorium ble oppnevnt i statsråd 29. mai 1955. Formann bergingeniør K. INGVALDSEN, viseformann professor J. A. W. BUGGE, medlemmer konservator J. A. DONS, professor A. HOFSETH og overrettssakfører O. H. MEDBØE. I november 1955 fremla fellesstyret på departementets anmodning en lengre innstilling om organisasjon og arbeidsfordeling i forbindelse med spørsmålet om N. G. U. bør flyttes til Trondheim. Bugge og Dons leverte en egen redegjørelse. Etter at departementets innstilling om saken forelå som stortingsinnstilling 87 (1956) sendte Bugge og Dons inn sine begrunnende søknader om avskjed, idet de ikke ønsket å medvirke til gjennomføring av en ordning som etter deres mening var uriktig. De to geologer i styret ønsker bl. a. en fullstendig sammenslåing av institusjonene under ledelse av en overdirektør med utstrakt innsikt også i geologi. Hovedkontoret for den geologiske avdeling foreslår de henlagt til Oslo hvor den sikres hensiktsmessige lokaler ved nybygg. Avskjed ble innvilget i statsråd 14. september 1956 uten at det ble oppnevnt nye medlemmer. Saken behandles av Stortinget høsten 1956.

Norges geologiske undersøkelse.

Dr. philos. TRYGVE STRAND sluttet 29. februar 1956 i stillingen som statsgeolog, for å tiltre som professor i geologi ved Universitetet i Oslo.

Cand. real. JOHANNES FÆRDEN sluttet 31. desember 1955 i stillingen som statsgeolog, og er blitt ansatt som geolog ved A/S Norsk Bergverk.

Engelsk geolog, dr. philos. PETER PADGET, og finsk geolog, EERO PEHKONEN, som har vært midlertidig ansatt som geologer, sluttet 30. april 1956 og er vendt tilbake til sine hjemland.

Dr. philos. CHRISTOFFER OFTEDAHL ble ansatt som statsgeolog I fra 1. mars 1956.

Cand. real. THOR SIGGERUD ble ansatt som statsgeolog II fra 1. juli 1956.

Cand. real. ROLF W. FEYLING-HANSEN ble ansatt som statsgeolog II fra 1. april 1956.

Cand. real. FINN J. SKJERLIE ble ansatt midlertidig som statsgeolog II fra 1. mai 1956.

Belgisk geolog, licencié TONY VAN AUTENBOER, er ansatt midlertidig som vitenskapelig assistent fra 9. februar 1956.

Amerikansk geolog, PAUL H. REITAN B. A., er ansatt midlertidig som vitenskapelig assistent fra 1. juli 1956.

Statsgeolog OLAF ANTON BROCH er 9. mars 1956 vendt tilbake etter endt permisjon.

Statsgeolog TORE GJELSVIK har fått forlenget permisjon til utgangen av 1956 for å arbeide som teknisk ekspert for F. N. i Tyrkia.

Universitetet i Oslo.

Dr. philos. IVAN TH. ROSENQVIST ble i statsråd 14. juni 1956 beskikket til professor i sedimentologi og geoteknikk ved Universitetet i Oslo.

Geologisk Institutt.

Statsgeolog, dr. philos. TRYGVE STRAND er fra 1. mars 1956 utnevnt til professor i geologi.

Cand. real. BJØRN G. ANDERSEN er fra 1. juli 1956 blitt universitetetsstipendiat i kvartærgeologi.

Cand. real. GERD BREVIG LIESTØL er fra 1. juli 1956 ansatt som vitenskapelig assistent.

Mineralogisk-Geologisk Museum.

Professor dr. TOM. F. W. BARTH var leder for den norske delegasjon til den Internasjonale Geologkongress i Mexico City september 1956.

Assistent, cand. real. KNUT HEIER har permisjon i ett år fra 1. juli 1956, til studier ved Oxford University i England.

Cand. mag. THOR SVERDRUP er ansatt som vikar under Heiers permisjon.

Cand. mag. KNUT ØRN BRYN er ansatt som assistent ved røntgenlaboratoriet fra 1. september 1956 til juni 1957.

Forsker OLAV H. J. CHRISTIE er ansatt som laborant for samme tidsrom.

ALF GRANLI, preparant ved Mineralogisk-Geologisk Museum, kasserer for Norsk Geologisk Forening, har pr. 1. september 1956 vært ansatt ved Universitetet i 40 år.

Paleontologisk Institutt.

Dr. WALTER C. SWEET, PH. D. (The Ohio State University, Colombus, Ohio) arbeider som Fulbright Research Scholar fra 15. september 1956, for å undersøke Oslofeltets mellom-ordoviciske cephalopoder.

Eksamener.

Matematisk-naturvitenskapelig embetseksamen med Mineralogi-petrografi som hovedfag er i vårsemesteret 1956 fullført av

FREDRIK HAGEMANN. Avhandling: «En stratigrafisk-petrografisk undersøkelse av silur på Hadeland».

Håkon Ø. Lien. Avhandling: «En geologisk og petrografisk beskrivelse av de vestlige traktene på kartblad Hattfjelldal».

Gerd Brevig Liestøl. Avhandling: «Noen petrografiske og mineralogiske undersøkelser omkring pegmatittgangene i Langesundsfjorden».

Cand. real. Håkon Ø. Lien er fra 1. juli 1956 ansatt som geolog ved A/S Sydvaranger, Kirkenes.

Gæa Norvegica.

På julemøte 2. desember 1955 ble preparant Alf Granli utnevnt til foreningens første æresmedlem. På samme møte ble konservator Johannes A. Dons slått til ridder av Den gyldne hammer.

Universitetet i Bergen.

Geologisk institutt.

Dosent dr. Anders Kvale har fått permisjon i ett år fra 1. juli 1956, til et opphold i Sveits, hvor han etter anmodning fra Eidgenössische Technische Hochschule i Zürich skal bearbeide materiale av strukturundersøkelser i Gotthardområdet, etterlatt av avdøde professor Niggli. Han skal dessuten foreta studiereiser i Alpene.

Førstekonservator Hans Holtedahl har fått permisjon i ett år fra 1. mai 1956, for med Fulbrightstipendium og stipendium fra Norges Almenvitenskapelige Forskningsråd å studere marin geologi ved Scripps Institution of Oceanography, La Jolla, California.

Cand. real. Markvard A. Sellevoll er fra 1. juli 1956 til 30. juni 1956 ansatt som assistent og vikarierende foreleser ved Geologisk institutt.

Eksamen.

Matematisk-naturvitenskapelig embetseksamen med Mineralogi-petrografi som hovedfag er i høstsemesteret 1955 fullført av Finn J. Skjerlie. Avhandling: «Geologiske undersøkelser mellom Sogndalsdalen og Fjærlandsfjorden i Indre Sogn».

INTERNATIONAL UNION OF CRYSTALLOGRAPHY.

Den fjerde generalforsamling og internasjonale kongress vil bli holdt i Montreal, Canada, fra 10. juli til 17. juli 1957. Dessuten vil det bli symposier over spesielle emner 18. og 19. juli. Det er også planlagt ekskursjoner i provinsene Quebec og Ontario. Nærmere opplysninger kan fås fra sekretæren i den norske nasjonalkomité for krystallografi, professor Ivar Oftedal, Mineralogisk institutt, Blindern, Oslo.

Fra sekretæren i *The Geochemical Society* har N.G.T.'s redaksjon mottatt følgende:

THE GEOCHEMICAL SOCIETY.

At the November meeting of the Geological Society of America, held in New Orleans, Louisiana, the Geochemical Society was organized. The objective of the new Society, as stated in the constitution, is to «encourage the application of chemistry to the solution of geological and cosmological problems». The consensus is that this should be given the broadest possible interpretation; it is hoped that not only chemists and geologists, but also physicists, biologists, oceanographers, meteorologists, mathematicians and other natural scientists interested in joint attacks on problems in the earth sciences will join the Society and help to further its objects.

There are no plans to start a new journal of geochemistry; publication of geochemical articles in existing earth science journals will be encouraged. In addition to that function and sponsoring geochemical sessions at meetings of appropriate scientific societies, the Geochemical Society intends to work for wider and more thorough educational opportunities in geochemistry, to seek closer co-ordination of geochemical investigations through a Research Committee, and to give Geochemistry specific representation on interdisciplinary earth science groups. The Council will welcome suggestions of other functions that the Society should, or might, perform.

Nærmere opplysninger samt søknadsskjema for medlemskap fås ved henvendelse til sekretæren, John C. Maxwell, Department of geology, Princeton University, Princeton, New Jersey.

MEDLEMSLISTE

à jour oktober 1956.
[1]: korresponderende medlem.
*: livsvarig medlem.
Tallet i parentes er innvalgsåret.
(S), stifter (18. februar 1905).

*Adamson, Olge J., dr. Postboks 42, Smedstad pr. Oslo (1945).
Ahlmann, Hans W:son, professor. Kgl. Utriksdepartementet, Gustav Adolfs torg, Stockholm. (1919).
Andersen, Bjørn, univ.stip. Geologisk institutt, Blindern, Oslo (1952).
Asklund, Bror, statsgeolog, Sveriges Geologiska Undersökning, Stockholm 50. (1938).
*Bache, Laura, lektor. Eiksbo, vei 509, Eiksmarka, Røa, Oslo (1931).
*Backlund, Helge, professor. Mineralogisk-geologiska Institutionen, Uppsala 1. (1919).
Baker, Donald, B. Sc. Dept. of Geology, Princeton University, Princeton, N. J., U.S.A. (1951).
Bakken, Asbjørn, lektor. Voss Landsgymnas, Voss. (1954).
*Barth, Tom. F. W., professor. Geologisk museum, Oslo 45. (1921).
Bergersen, Birger, statsråd. Anton Schjøthsgt. 13, Oslo. (1921).
Bertheau-Hansen, Chr., bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1942).
Birkeland, Tor, lektor. Avaldsnesgt. 36, Stavanger. (1946).
Bjerrum, Lauritz, direktør. Norges geotekniske institutt, Blindern, Oslo. (1952).
*Bjørlykke, Harald, dr. Norsk Bergverk, Christian August's gate 15, Oslo. (1923).
Boughton, Eric. Hay Tor, 921 Harrow Rd., Wembley, Middlesex, England. (1932).
*Broch, Olaf Anton, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1920).
Bruun, B., ingeniør. N.G.U. Geologisk museum, Oslo 45. (1938).
Bryhni, Inge, stud.real. Geologisk institutt, Universitetet i Bergen. (1955).
Brøndmo, Knut, bergingeniør. Løkken Verk. (1955).
*Braastad, Johan, dr. Postboks 808, Oslo. (1913).
Bugge, Arne, dr. Utsiktsveien 21, Stabekk. (1914).
*Bugge, Carl, direktør. Håkon den gode's vei 12, Vindern, Oslo. (S).
*Bugge, Jens, professor, Norges tekniske høgskole, Trondheim. (1940).

*Bulman, O. M. B., prof. Sedgwick Museum, Cambridge, England. (1951).

*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1917).

Cameron, Richard. Dept. of Geology., Ohio State Univ., Columbus 10, Ohio, U.S.A. (1956).

*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).

Caster, Kenneth, professor. Dept. of Geology and Geography, University of Cincinnati, Cincinnati, Ohio, U.S.A. (1953).

*Chapman, Charleton A., professor. University of Illinois, Urbana, Ill., U.S.A. (1949).

*Chen Kwan Yuan, B. Sc. Geological Institute, National Peking University, Peking, Kina. (1951).

*Christensen, Erna, kjemiker. N.G.U. Geologisk Museum. Oslo 45. (1955).

Collini, Bengt, fil.lic., laborator. Kungl. Lantbrukshögskolan, Institutionen för Marklära, Uppsala 7, Sverige. (1949).

Craig, H. B., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1949).

*Dahl, Eilif, cand. real. Botanisk institutt, Norges Landbrukshøgskole, Vollebekk. (1946).

Dahl, Erling, ingeniør. Skogveien 1, Notodden. (1945).

Dahlström, Elis, fil. lic. Narvavägen 31, Stockholm Ö. Sverige. (1945).

Danielsen, Anders, konservator. Botanisk museum, Bergen. (1949).

*Danielsen, D. A., rektor, Kongensgt. 15, Kristiansand S. (1945).

*Devore, George W., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1948).

Dietrichson, Brynjulf, bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1917).

Donnay, J. D. H., professor. Johns Hopkins University, Baltimore 18, Maryland, U.S.A. (1937).

*Dons, Johannes A., konservator. Geologisk museum, Oslo 45. (1941).

*Eckermann, Harry von, professor. Edeby pr. Ripsa, Sverige. (1937).

Edelman, Nils, dr. Havori gruve, Viljakkala, Finnland. (1956).

Egeberg, F. P., bergingeniør. Rådhusgata 5b, Oslo (1939).

Elliott, Robert B., dr. Department of Geology, The University, Nottingham, England (1954).

Enkovaara, Antti, magister. Oulainen, Finnland. (1947).

Eriksen, Edv. Andreas, bergingeniør. Uranienborgveien 11c, Oslo (1945).

*Eskola, Pentti, professor. Min.-geol. Inst., Universitetet, Helsingfors. (1919).

Espeland, Margaret, B. Sc. Hus 2, Vei 3672, Nordstrandhøgda, Oslo (1950).

*Falkenberg, Otto, ingeniør. Priorveien 7, Smestad, Oslo. (1914).

Feyling-Hanssen, Rolf, statsgeolog. N.G.U. Geologisk museum, Oslo 45, (1950).

*Fægri, Knut, professor. Botanisk museum, Bergen. (1935).

Færden, Johannes, geolog. A/S Norsk Bergverk, Chr. Augustgt. 15, Oslo. (1948).

*Føyn, Sven, direktør. Norges geologiske undersøkelse, Oslo 27. (1932).

Garthus, Torbjørn, lærar. Garthus, Valdres. (1943).

Gavelin, Sven, professor. Mineralogiska Institutet, Stockholm's Högskola, Stockholm, Sverige. (1954).
Gilberg, Gunnar, fil. lic. Stockholm Högskola, Stockholm, Sverige. (1952).
*Gjelsvik, Tore, statsgeolog. Evjebakken 18, Sandvika. (1945).
Gjessing, Just, amanuensis. Geografisk institutt, Blindern, Oslo. (1953).
*Gleditsch, Chr., geolog. Bentsegt. 10, Oslo, (1941).
*Green, John, C., B. A. 183 North Main Street, West Hartford, Conn., U.S.A. (1954).
Grennes, Johannes, ingeniør. Statens råstofflaboratorium, Østmarka, Trondheim. (1945).
*Grip, Erland, fil. lic. Boliden, Sverige. (1938).
*Grønlie, Arne, rektor. Mo komm. høgre almenskole, Mo i Rana. (1943).
*Hagemann, Fredrik, cand. real. Hjelmsgt. 6a, Oslo (1951).
*Hagner, A. F., professor. Dept of Geology, University of Illinois, Urbana, Ill., U.S.A. (1947).
Hansen, Kaj, dr. Gammeltoftsgade 16, København K. (1947).
*Harry, W. T., B. Sc. University, Dundee, Scotland. (1949).
*Hartley, Jack, B. Sc. Department of Geology, University, Leeds 2, England. (1949).
*Hawkes, Leonard, professor, D. Sc., F.R.S. 26 Moore Lane, Rickmansworth, Herts., England. (1915).
*Heber, Gustav, advokat. Oscarsgt. 49. Oslo (1938).
*Heber, Gustav, bygningsingeniør. Oscarsgt. 46b, Oslo. (1942).
*Heier, K. S., cand. real. Geologisk museum, Oslo 45. (1952).
*Heintz, Anatol, professor. Geologisk museum, Oslo 45. (1926).
*Heintz, Natascha, cand. real. Homans vei 24, Blommenholm. (1951).
Heltzen, Anders M., bergingeniør. Sulitjelma Gruber, Sulitjelma. (1941).
*Helverschou, Kaare, disponent. Villavegen 9, Frøen, Oslo. (1943).
*Henderson, Donald M., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1949).
*Henningsmoen, Gunnar, konservator. Geologisk museum, Oslo 45. (1941).
*Hernes, Ivar, amanuensis. Geologisk institutt, Bergen. (1947).
*Hesse, P. A. Jürgen, bergingenjör. Nynäsvägen 304, Stockholm/Enskede Sverige. (1936).
*Hessland, Ivar, professor. Stockholms Högskola, Stockholm. (1947).
Higazy, R., prof. Faculty of Science, University of Alexandria, Egypt. (1947).
Hjelmquist, Sven, professor. Geologiska Inst., Lund, Sverige. (1949).
Hofseth, Arne, professor. Norges Tekniske Høgskole, Trondheim. (1952).
Holmberg, Sigurd, amanuens. Lervägen 24, Lund, Sverige. (1953).
Holmesland, P. B., overingeniør. Herøya pr. Porsgrunn, (1954).
Holmsen, Bjarne, ingeniør. Charlotte Andersens vei 28, Smestad, Oslo. (1941).
*Holmsen, Gunnar, statsgeolog. Skådalen, Oslo. (1908).
*Holmsen, Per, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1940).
Holtedahl, Hans, førstekonservator. Geologisk institutt, Universitetet i Bergen (1948).

*Holtedahl, Olaf, professor. Geologisk institutt, Blindern, Oslo. (1908).
*Howe, Henry, V., professor. School of Geology, Louisiana State University, Baton Rouge, Louisiana, U.S.A. (1953).
Huseby, Fredrik, cand. real. Geologisk institutt, N. T. H., Trondheim (1951).
*Høeg, Ove Arbo, professor. Farmasøytisk institutt, Blindern, Oslo. (1924).
Høeg-Omdal, S. K., byråsjef. Utgarveien 12, Jar pr. Oslo. (1945).
Ihle, Ole K., stud. real. Norges geologiske undersøkelse, Oslo. (1956).
Ingvaldsen, Karl, bergingeniør. Røros kobberverk, Røros. (1956).
*Isachsen, Fridtjov, professor. Geografisk institutt, Blindern, Oslo. (1929).
Iversen, Anker, preparant. Geologisk institutt, N.T.H., Trondheim. (1953).
*Jakhelln, Johanne Hødal, cand. real. United Nations, Box 20, Gr. Central P. O., New York 17, N. Y., U.S.A. (1943).
Jakhelln, Kirsten, fru. Irisvegen 18, Berg, Oslo. (1953).
Jensen, Einar, dr. Villavegen 3, Rjukan. (1939).
Johansen, Erling, stipendiat. Kråkerøy, Fredrikstad. (1953).
Jøsang, Ottar, stud. mag. scient. Geologisk museum, Oslo 45. (1956).
*Kautsky, Gunnar, statsgeolog. Sveriges Geologiska Undersökning, Stockholm 50, Sverige. (1952).
*Kennedy, W. Q., D. Sc., F. R. S., professor. University of Leeds, Leeds 2, England. (1947).
*Kiil, Erling, bergingeniør. Brantenborgveien 2, Slemdal, Oslo. (1922).
*Klompé, Theo., professor. University of Indonesia, Geological Section, Dj. Ganeca 10, Bandoeng, Java, Indonesia. (1947).
Klüver, Emil, ingeniør. Statens toll-laboratorium, Oslo. (1926).
*Kolderup, Niels-Henr., professor, Geologisk institutt, Bergen. (1919).
*Kollerud, Martha, cand. mag. Trondheimsveien 10, Oslo. (1919).
Kraft Johanssen, J., direktør. A/S Sydvaranger, Kongens gt. 5, Oslo. (1955).
*Krauskopf, K. B., professor. Geol. Dept. Stanford University, Stanford, Cal. U.S.A. (1953).
*Kristoffersen, K., dr. A/S Norsk Jernverk, Mo i Rana. (1941).
*Kullerud, Gunnar, dr. Geophysical Laboratory, 2801 Upton Street, Washington 8, D. C., U.S.A. (1948).
Kulling, Oskar, statsgeolog. Sveriges Geologiska Undersökning. Stockholm 50, Sverige. (1953).
Kvale, Anders, dosent. Geologisk institutt, Bergen. (1936).
Kvalheim, Aslak, laboratoriesjef. Statens råstofflaboratorium, Østmarka, Trondheim. (1944).
Landergren, Sture, dr. Sveriges Geologiska Undersökning, Stockholm 50. (1943).
Landmark, Einar, direktør. Tidemandsgt. 14, Oslo. (1941).
Landmark, Kåre, konservator. Tromsø museum, Tromsø. (1943).
*Larssen, Kari Egede, geol. ass. Norges geologiske undersøkelse, Oslo. (1956).
*Larsson, Tollef, cand. real. Engene Fabrikker, Sætre i Hurum. (1945).
Laursen, Dan., lektor. Julius vej 6, Gentofte, København. (1947).
*Lenander, N. E., direktör. Norrlandsg. 7—9, Stockholm, Sverige. (1914).
Lien, Håkon, geolog. A/S Sydvaranger gruber, Kirkenes. (1956).

Liestøl, Olav, glasiolog. Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1947).
*Lindley, Henry W., dr. Die techn. Hochschule, Wullner Str. 2, Aachen, Tyskland. (1928).
Ljunggren, Pontus, fil. dr. Geologiska Institution, C. T. H., Gibraltarsgatan 5a, Göteborg, Sverige. (1952).
Logn, Ørnulf, cand. real. Fosdalen Bergverks A/S, Malm. (1953).
Lund, Kjell, direktør. A/S Sulitjelma Gruber, Fr. Nansenpl. 6, Oslo. (1938).
*Lund, Lars, mag. sc. Forsvarets forskningsinstitutt, Kjeller pr. Lillestrøm, (1943).
Lund, Worm, bergingeniør. A/S Sydvaranger, Kongensgt. 5, Oslo. (1941).
*Lundby, Sven Erik, arkitekt. Norges byggforskningsinstitutt, Blindern, Oslo. (1937).
Løddesøl, Åsulv, direktør. Det norske myrselskap, Rosenkrantzgt. 8, Oslo. (1938).
Løvaas, Gunnar, bergingeniør. Skorovas Gruber, Skoravatn p. å. (1949).
*Låg, J., professor. Norges landbrukshøgskole, Vollebekk. (1943).
Mackenzie Scott, Wm. Geophysical Laboratory, 2801 Upton Street, Washington 8, D. C., U.S.A. (1956).
Magnusson, H. N., överdirektör. Vallhallavägen 46, Stockholm. (1937).
*Major, Harald, geolog. Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1944).
Marklund, Nils, fil. lic. Min. geol. Inst., Uppsala 1. (1951).
*Marmo, Vladi, magister. Mineralogisk Institut, Universitetet, Helsingfors, (1949).
*Marstrander, Henning, bergingeniør. 2924 Leland Road, Homewood, Birmingham 9, Alabama, U.S.A. (1917).
*Marthinussen, Marius, lektor. Ski komm. h. almenskole. Ski. (1931).
*Mason, Brian, dr. The American Mus. of Nat. History, Central Park West at 79th Street. New York 24. N. Y., U.S.A. (1953).
McCulloh, Thane H., M. Sc. Division of Physical Sciences, University of California, Riverside, Cal., U.S.A. (1951).
Mellis, Otto, dr. Min. Inst., Stockholms Högskola, Stockholm. (1951).
[1]Michot, Paul, professor. Inst. de Géologie, Université de Liege, Belgia. (1951).
Monsen, Astrid, konservator. Nyhaugsveien 10, Minde pr. Bergen. (1953).
Mortensen, Odd, cand. real. Postboks 519, Bergen. (1938).
Mortensen, Magne, professor. Norges tekniske høgskole, Trondheim. (1948).
Munck, Sole museumsinspektør. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1948).
*Murray, Grover, E., professor. School of Geology, Louisiana State University. Baton Rouge, Louisiana, U.S.A. (1953).
*Neumann, H., førstekonservator. Geologisk museum, Oslo 45. (1940).
Nilssen, Borghild, stud. real. Geolgiske museum, Oslo 45. (1956).
*Noe-Nygaard, Arne, professor. Østervoldgade 7, København K. (1934).
Norin, Erik, professor. Mineralogisk-geologiska Institution, Uppsala 1. (1947).
*Nosow, Edmund, dr. Box 282, Kentucky Geological Survey, Hopkinsville. Kentucky, U.S.A. (1953).

*Nørregaard, E. M., cand. mag. Mineralogisk og Geologisk Museum Østervoldgade 7, København K. (1917).
*Oftedahl, Christoffer, statsgeolog. Festningsv. 6 Stabekk. (1941).
*Oftedal, Ivar, professor. Mineralogisk institutt Blindern, Oslo. (1918).
*Orvin, A. K., bergingeniør. Håkon den godes vei 21, Vindern, Oslo. (1913).
Ottesen, P. O., lensmann. Manger pr. Bergen. (1915).
*Padget, Peter, dr. Geol. dept., University of Leeds, Leeds 2, England. (1954).
Paulsen, Nils, bergingeniør. Berg, Maridalen, Oslo. (1947).
Pehkonen, Eero, geolog. Geologiska Forskningsanstalten i Finnland, Boulevardgt. 29, Helsingfors, Finnland. (1955).
*Pettersson, Adam, bergingeniør. Lysaker ved Oslo. (1918).
*Poulsen, Arthur O., statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1941).
*Quensel, Percy, professor. Stockholms Högskola, Stockholm. (1916).
*Ramberg, Hans, professor. Dept. of Geology, Univ. of Chicago, Chicago 37, Ill., U.S.A. (1941).
Ramsli, Gunnar, cand. real. Landbruks dept., Victoria terrasse 3, Oslo. (1948).
Rankama, Kalervo, professor. Geologisk Institut, Universitetet, Helsingfors. (1947).
Regnéll, Gerhard, dr. Geologisk-paleontologiska Inst., Lund, Sverige. (1947).
*Rosendahl, Halvor, konservator. Geologisk museum, Oslo 45. (1918).
*Rosenlund, A. L., jernbanegeolog. Drammensveien 103, Oslo. (1912).
Rosenqvist, Ivan Th., professor. Geoteknisk institutt, Blindern, Oslo. (1941).
Ross, Harald N., direktør. Kongsberg sølvverk, Kongsberg. (1947).
Rutherford, G. K., M. Sc., Norges landbrukshøgskole, Vollebekk. (1952).
Rønning, O., ingeniør. Konvallvn. 52, Oslo. (1938).
Sahlin, Anders, ingenjör. L. M. E., Stockholm 32, Sverige. (1953).
Samuelsen, Andreas, lektor. Engeveien 10, Bergen. (1929).
*Scheumann, K. H., professor. Universität Bonn, Königstrasse 67, Bonn a. Rhein, Tyskland. (1928).
Sellevoll, M. A., cand. real. Geologisk Institutt, Universitetet i Bergen (1954).
Selmer-Olsen, Rolf S., amanuensis, Geol. Inst., N.T.H., Trondheim. (1948).
Semb. Gunnar, forsøksleder. Norges landbrukshøgskole, Vollebekk. (1941).
*Siggerud, Thor, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1951).
Skjerlie, Finn, geolog. Norges geologiske undersøkelse, Oslo 27. (1951).
*Skjeseth, Steinar, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1949).
Skordal, Asbiørn, geolog. «Vestråt». Elvegaten 18, Trondheim. (1946).
Skålvoll, Harald, cand. mag. Norges geologiske undersøkelse, Oslo 27. (1956).
Smaadal, Gerd Vogt, cand. mag. Halvorsens vei 36, Blommenholm. (1951).
Smith, H. H., bergingeniør. Drachmannsgatan 2, Bromma, Stockholm. (1925).
*Sobral, José M., dr. Avenida de los incas 3020, Buenos Aires. (1931).
Soot-Ryen, T., direktør. Tromsø museum, Tromsø. (1946).
*Spjeldnæs, Nils, cand. real. Geologisk museum, Oslo 45. (1946).
*Steinsvoll, Søren, overgartner. Botanisk hage, Trondheimsvn. 23, Oslo. (1942).
Stenvik, Kr., Christian Michelsensgt. 19, Oslo. (1946).
Storebakken, H. C., cand. real. «Sætra», Svelvik, Vestfold. (1940).

*Strand, Trygve, professor. Geologisk Institutt, Blindern, Oslo. (1927).
*Strøm, Kaare, professor. Limnologisk institutt, Blindern, Oslo. (1932).
*Størmer, Leif, professor. Geologisk museum, Oslo 45. (1925).
Sund Tore, dosent. Norges handelshøyskole, Bergen. (1943).
Sunde, Albert C., bergingeniør. Oscarsgt. 46, Oslo. (1948).
*Sverdrup, Thor Lorck, cand. mag. Geologisk museum, Oslo 45. (1956).
*Sverre, Erik, jr., disponent. Drammensvn. 44b, Oslo. (1946).
Svinndal, Sverre, geolog. A/S Norsk Bergverk, Søve, Ulefoss. (1953).
Sæbø, Per Chr., cand. mag. Geologisk museum, Oslo 45. (1956).
Sæther, Egil, amanuensis. Harestua. (1943).
*Sørbye, Ruth, C., cand. real. Geologisk institutt, Universitetet i Bergen. (1941).
*Sørensen, Henning, mag. scient. Mineralogisk Museum, Østervoldgade 7, København K. (1952).
Thorslund, Per, professor. Paleontologiska Institutionen, Uppsala 8. (1940).
*Trøften, Einar, bergingeniør. Sulitjelma. (1921).
*Trøften, Per-Fredrik, bergingeniør. Geofysisk Malmleting, Trondheim. (1956).
*Undås, Isak, lektor. Fløenbakken 8b, Bergen. (1931).
*Vogt, Thorolf, professor. Norges tekniske høgskole. Trondheim. (1908).
Vokes, Frank Marcus, M. Sc. N.G.U., Geologisk Museum, Oslo 45. (1954).
*Wager, L. R., professor, D. Sc., F.R.S. The University Museum, Oxford, England. (1949).
[1]Wegmann, C. E., direktør. Fbg. de l'hôpital 43, Neuchátel, Schweiz. (1925).
Werenskiold, Werner, professor. Postboks 220, Lysaker. (1909).
*Wickmann, Frans E., professor, Riksmuseet, Stockholm 50. (1945).
Wilhelmsen, John, tekn. ass., Norges geologiske undersøkelse, Oslo 27. (1956).
Winsnes, Thore, geolog. Abbedikollen 34, Ullern. (1947).
Wærn, Bertil, fil. lic., bibliotekar. S:t Johannesg. 22, Uppsala. (1947).
*Zachariasen, William, professor. Ryerson Physical Laboratory, University, Chicago 37, Ill., U.S.A. (1929).
Ødmann, Olof H. R., professor. Inst. för mineralogi och geologi, Kungl. Tekn. Högskolan, Stockholm 70, Sverige. (1953).
*Øien, Fritz, bergingeniør. Statens teknologiske institutt, Akersveien 24c, Oslo. (1945).
*Ørvig, Tor, dr. Paleozoologiska Avd., Riksmuseet, Stockholm 50. (1941).
Øverlie, Olav, bergingeniør. Rødsand gruber, Rausand om Molde. (1949).
*Ånerud, Kåre, lektor. Mossevegen 220, Nordstrand, Oslo. (1931).
Aasgaard, Gunnar, bergmester. Elgesetergt. 51, Trondheim. (1921).

2 korresponderende medlemmer.
112 livsvarige medlemmer.
118 årsbetalende medlemmer.
232 medlemmer.